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## THE COMPOSITION OF GRAIN SORGHUM KERNELS.[1]


J. A. LE CLERC AND L. H. BAILEY.


### INTRODUCTION.

This paper gives the average results of a large number of analyses of the seed of the grain sorghums. The samples analyzed were from crops grown in the Panhandle of Texas by the Office of Cereal Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture, in the five years from 1908 to 1912, inclusive. The investigation was undertaken for the purpose of ascertaining how the composition of these grain sorghums varies in different years and whether such variation is a result of the climatic conditions prevailing during the growing and pregrowing periods. In addition to giving the average composition of those grain sorghums that have been grown quite extensively, this paper contains analyses of a small number of samples of the grain of certain sorghums which are not so well known—shallu and broomcorn. There are also reported results of analyses of bread made in part from grain sorghum meal.

The chemical analyses here given when compared with analyses of the ordinary cereals may serve as an index to the food value of the grain sorghums. The results show that these grains may be favorably likened to the cereals in food value. A general knowledge of this fact should serve to stimulate and to encourage a wider use of the sorghums for human consumption, as well as for stock feeding.


[1] Contribution from the Laboratory of Plant Chemistry, Bureau of Chemistry, United States Department of Agriculture. Published by permission of the Secretary of Agriculture. Received for publication November 1, 1916.

### THE GRAIN SORGHUMS.

The grain sorghums, which are indigenous to Africa and India, are of great antiquity and are grown extensively in those countries and China. They belong botanically to the general classification of sorghums (*Andropogon sorghum*) (3).[2] Among them may be mentioned milo, kafir, durra, and kaoliang, and crosses or hybrids among these. They are drought-resistant plants, and it is due to this fact more than to any other that they may be grown successfully and profitably in the dry-land region of the Great Plains. The cultivation in this region of such grains as milo and kafir is highly desirable, since the yield is greater than can be obtained from almost any other crop. The actual yield in dry-land areas is sometimes as high as 50 or even 75 bushels per acre (5).

The sorghum belt of this country is the southern part of the Great Plains area. It is nearly 400 miles wide and 1,000 miles long (4). The grain sorghums are grown to such an extent in the United States,—principally within the area peculiarly adapted to their growth,—that in 1910 over 3,000,000 acres were devoted to their culture, the crop having a value of about $30,000,000.

Where grown in the Old World the grain sorghums are commonly used as human food and, indeed, often furnish the chief article of diet. In the United States they are generally employed as stock and poultry feeds, for which purpose they have been successfully used, as they are very similar in composition to corn. Recently attempts have been made in this country to subject sorghum grain to the process of milling and to employ the ground grain in the same way that cornmeal is used. Inasmuch as these grains do not contain gluten as such, meal made from them can not be used alone, as can wheat flour, for making yeast-risen bread. There seems to be no reason, however, why such meal should not be used as a partial substitute for wheat flour in the making of bread. Undoubtedly it can be used in making batter cakes and similar products.

Milo, kafir, and the other grain sorghums might be used with profit for the manufacture of breakfast food and for popping, as substitutes for popcorn (6). Moreover, since these grains contain practically the same proportion of carbohydrates as does maize, they can perhaps be profitably employed for the manufacture of alcohol or for the manufacture of a sirup similar to glucose or corn sirup. This suggestion is made as a result of the work done in Oklahoma by Baird (1) and by Baird and Francis (2). Baird states that kafir grain

[2] Reference is made by number to "Literature cited," p. 16.

compares favorably with maize in digestibility, as shown by digestion experiments with chickens, in composition as shown by chemical analysis, and in suitability for the production of alcohol or glucose. His results also show that a crop of kafir removes less plant food from the soil than does a crop of maize.

### METHODS OF ANALYSIS.

The methods of analysis used in this investigation were those given in Bureau of Chemistry Bulletin 107, revised, and known as the methods of the Association of Official Agricultural Chemists (7).[3] The weight per bushel was obtained by the use of a miniature bushel or grain tester. The weight per 1,000 kernels was obtained by counting from each sample lots containing 200 and 300 kernels, respectively, and weighing them. The agreement should be within half a gram per 1,000 kernels.

### RESULTS OF BREAD-MAKING TEST.

From experiments in the use of grain-sorghum meals as part substitutes for flour in bread-making, it appears that it is possible to make from a mixture of 25 percent milo, kafir, or other grain-sorghum meal, and 75 percent of good wheat flour, a very pleasing loaf of bread. Such bread has essentially the same composition as bread made from wheat flour, except that it contains somewhat more ash and fiber than does wheat flour bread. The striking difference between these sorghum breads and bread made from wheat flour alone is in the color, that from the sorghum-wheat mixture resembling somewhat a loaf made from rye-wheat mixture. Table 1 shows the composition of bread made with wheat flour alone and of bread in which milo, kafir, or kaoliang meal has been substituted for 25 percent of the flour.[4]

TABLE 1.—*Analyses of bread made from wheat flour alone and from mixed flours containing 25 percent of grain-sorghum meal.*

| Kind of bread. | Water. | Ash. | Protein. | Fat. | Fiber. |
|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| All wheat | 35.00 | 1.26 | 9.60 | 1.88 | 0.13 |
| Milo and wheat | 32.76 | 1.46 | 9.25 | — | .35 |
| Kafir and wheat | 30.15 | 1.66 | 9.78 | — | .36 |
| Kaoliang and wheat | 35.70 | 1.43 | 8.94 | — | .33 |

[3] The nitrogen determinations were made in the Nitrogen Laboratory, Bureau of Chemistry, under the supervision of T. C. Trescot.

[4] The baking experiments were carried on by Miss H. L. Wessling, of the Laboratory of Plant Chemistry, who also did the analytical work on the breads.

### RESULTS AND DISCUSSION OF ANALYSES.

Of the analyses of grain sorghums only the minimum, maximum, and average results are given for each kind of grain for the series of years during which it was grown. These figures represent hundreds of analyses made during a period of five years, from 1908 to 1912, inclusive. It is believed, therefore, that they will give a very clear idea of the possible variation in the composition of sorghum grains grown in a particular section of the country and will show to what extent the composition has been affected by climatic conditions.

Table 2 shows the minimum and maximum results and the average composition of the various grain sorghums for the series of years during which they were grown at Amarillo, Tex. The data are summarized in the last section of the table.

TABLE 2.—*Minimum, maximum, and average composition of various grain sorghums grown at Amarillo, Tex., 1908–1912.*

DURRA.

| Variety and analysis. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Carbo-hydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Grams* | *Pounds* |
| White, 35 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.05 | 1.44 | 11.25 | 2.22 | 1.06 | 68.08 | 20.7 | 51.9 |
| Maximum...... | 10.46 | 2.06 | 15.19 | 4.90 | 3.39 | 72.54 | 32.0 | 60.5 |
| Average....... | 9.49 | 1.74 | 13.69 | 3.52 | 1.48 | 70.08 | 28.2 | 56.4 |
| Buff, 4 samples, 1908–1909. | | | | | | | | |
| Minimum...... | 8.56 | 1.53 | 12.06 | 2.26 | 1.41 | 69.10 | 20.1 | 58.6 |
| Maximum...... | 10.58 | 1.82 | 15.00 | 4.26 | 1.80 | 73.14 | 34.5 | 59.9 |
| Average....... | 9.60 | 1.69 | 13.06 | 3.05 | 1.62 | 71.24 | 28.1 | 59.0 |

DURRA KAFIR.

| Variety and analysis. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Carbo-hydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| Blackhull, 28 samples. | | | | | | | | |
| Minimum...... | 8.18 | 1.76 | 12.44 | 2.92 | 1.32 | 65.42 | 17.6 | 46.7 |
| Maximum...... | 10.64 | 2.19 | 16.75 | 4.46 | 2.25 | 70.75 | 24.5 | 57.9 |
| Average....... | 9.49 | 1.98 | 14.38 | 3.56 | 1.70 | 68.84 | 22.3 | 55.1 |
| Palehull, 19 samples. | | | | | | | | |
| Minimum...... | 8.62 | 1.79 | 11.69 | 2.80 | 1.24 | 67.05 | 17.3 | 55.0 |
| Maximum ..... | 10.56 | 2.24 | 16.06 | 3.85 | 2.36 | 71.81 | 27.0 | 57.7 |
| Average....... | 9.79 | 1.90 | 14.88 | 3.43 | 1.57 | 69.42 | 22.3 | 56.2 |

TABLE 2.—*Minimum, maximum, and average composition of grain sorghums grown at Amarillo, Tex., 1908–1912.—Continued.*

KAFIR.

| Variety and analysis. | Water. | Ash. | Protein (N×6.25). | Fat. | Fiber. | Carbohydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Grams* | *Pounds* |
| Blackhull, 83 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.50 | 1.53 | 11.25 | 2.85 | 1.30 | 65.94 | 13.6 | 55.5 |
| Maximum...... | 10.65 | 1.99 | 15.94 | 4.00 | 1.89 | 72.79 | 29.4 | 60.3 |
| Average....... | 9.60 | 1.78 | 14.00 | 3.44 | 1.59 | 69.52 | 20.9 | 59.0 |
| Red, 67 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.63 | 1.52 | 9.69 | 2.56 | 1.22 | 69.08 | 14.7 | 53.6 |
| Maximum...... | 10.62 | 1.99 | 14.40 | 3.65 | 1.82 | 74.54 | 29.7 | 60.2 |
| Average....... | 9.71 | 1.74 | 12.37 | 3.14 | 1.48 | 71.54 | 20.3 | 58.2 |
| White, 19 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.76 | 1.55 | 11.31 | 2.78 | 1.18 | 70.04 | 15.7 | 55.6 |
| Maximum...... | 10.88 | 1.90 | 13.50 | 3.66 | 1.79 | 73.07 | 30.1 | 59.1 |
| Average....... | 9.84 | 1.67 | 12.44 | 3.30 | 1.50 | 71.46 | 23.1 | 57.4 |
| Dwarf, 11 samples, 1908–1909 and 1911–1912. | | | | | | | | |
| Minimum...... | 9.38 | 1.57 | 11.31 | 3.01 | 1.33 | 69.59 | 15.2 | 58.3 |
| Maximum...... | 11.03 | 1.72 | 13.87 | 3.55 | 1.64 | 72.65 | 22.1 | 59.6 |
| Average....... | 10.09 | 1.66 | 12.81 | 3.19 | 1.49 | 70.81 | 17.5 | 59.2 |

KAOLIANG.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| White, 11 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.70 | 1.58 | 11.50 | 4.07 | 1.09 | 68.85 | 14.5 | 55.8 |
| Maximum...... | 10.09 | 1.99 | 14.56 | 5.21 | 1.56 | 71.87 | 24.1 | 59.4 |
| Average....... | 9.18 | 1.81 | 13.56 | 4.91 | 1.26 | 69.34 | 19.7 | 57.7 |
| Blackhull, 9 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.79 | 1.63 | 11.13 | 3.39 | .96 | 67.59 | 15.4 | 55.0 |
| Maximum...... | 10.24 | 2.15 | 15.63 | 4.69 | 1.59 | 73.22 | 23.5 | 58.5 |
| Average....... | 9.48 | 1.88 | 13.06 | 3.97 | 1.26 | 70.38 | 18.6 | 56.8 |
| Brown, 72 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.25 | 1.53 | 10.25 | 3.07 | 1.06 | 65.85 | 13.7 | 50.3 |
| Maximum...... | 11.07 | 3.06 | 15.31 | 5.36 | 2.58 | 73.22 | 30.3 | 58.0 |
| Average....... | 9.38 | 1.87 | 13.42 | 4.16 | 1.39 | 69.84 | 19.2 | 56.0 |

MILO.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Standard, 68 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.02 | 1.33 | 9.81 | 2.44 | 1.26 | 69.53 | 27.8 | 56.4 |
| Maximum...... | 11.27 | 1.84 | 14.13 | 3.88 | 1.74 | 75.22 | 39.4 | 59.6 |
| Average....... | 9.33 | 1.63 | 12.63 | 3.16 | 1.49 | 71.86 | 36.2 | 58.1 |

TABLE 2.—*Minimum, maximum, and average composition of grain sorghums grown at Amarillo, Tex., 1908–1912.—Concluded.*

MILO.

| Variety and analysis. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Carbohydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Grams* | *Pounds* |
| Dwarf, 55 samples, 1908–1912. | | | | | | | | |
| Minimum...... | 8.11 | 1.43 | 9.19 | 2.85 | 1.27 | 69.23 | 25.1 | 55.0 |
| Maximum...... | 10.73 | 1.83 | 14.13 | 3.78 | 1.82 | 75.33 | 36.4 | 59.6 |
| Average....... | 9.38 | 1.63 | 12.06 | 3.27 | 1.47 | 72.20 | 31.4 | 58.2 |
| White, 19 samples, 1910–1912. | | | | | | | | |
| Minimum...... | 8.24 | 1.51 | 9.63 | 2.80 | 1.39 | 69.71 | 25.2 | 55.2 |
| Maximum...... | 10.45 | 1.84 | 14.44 | 3.67 | 1.86 | 74.45 | 35.5 | 58.5 |
| Average....... | 9.35 | 1.66 | 12.88 | 3.10 | 1.53 | 72.06 | 32.9 | 57.6 |
| Hybrid, 6 samples, 1911–1912. | | | | | | | | |
| Minimum...... | 9.21 | 1.55 | 12.13 | 2.47 | 1.59 | 65.90 | 27.1 | 50.0 |
| Maximum...... | 10.82 | 2.29 | 15.50 | 3.24 | 3.57 | 72.15 | 36.2 | 58.5 |
| Average....... | 10.03 | 1.83 | 14.13 | 2.91 | 2.21 | 68.97 | 32.4 | 56.1 |

SUMMARY.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Durra, 39 samples. | | | | | | | | |
| Minimum...... | 8.05 | 1.44 | 11.25 | 2.22 | 1.06 | 66.53 | 20.1 | 51.9 |
| Maximum...... | 10.58 | 2.06 | 15.19 | 4.90 | 3.39 | 73.14 | 37.3 | 60.5 |
| Average....... | 9.50 | 1.73 | 13.63 | 3.47 | 1.49 | 70.30 | 28.2 | 56.7 |
| Durra kafir, 47 samples. | | | | | | | | |
| Minimum...... | 8.18 | 1.76 | 11.69 | 2.80 | 1.24 | 65.42 | 17.3 | 54.1 |
| Maximum...... | 10.64 | 2.24 | 16.75 | 4.46 | 2.36 | 71.81 | 27.9 | 57.7 |
| Average....... | 9.61 | 1.95 | 14.19 | 3.51 | 1.65 | 69.08 | 22.3 | 55.6 |
| Kafir, 182 samples. | | | | | | | | |
| Minimum...... | 8.50 | 1.52 | 9.69 | 2.56 | 1.18 | 65.94 | 13.6 | 53.6 |
| Maximum...... | 11.03 | 1.99 | 15.94 | 4.00 | 1.89 | 74.34 | 30.1 | 60.2 |
| Average....... | 9.70 | 1.75 | 13.13 | 3.30 | 1.54 | 70.30 | 20.7 | 58.2 |
| Kaoliang, 92 samples. | | | | | | | | |
| Minimum...... | 8.25 | 1.53 | 10.25 | 3.07 | 0.96 | 65.86 | 13.7 | 50.3 |
| Maximum...... | 11.07 | 3.06 | 15.63 | 5.36 | 2.58 | 73.22 | 30.3 | 59.4 |
| Average....... | 9.37 | 1.87 | 13.37 | 4.23 | 1.36 | 69.84 | 19.2 | 56.3 |
| Milo, 150 samples. | | | | | | | | |
| Minimum...... | 8.02 | 1.33 | 9.19 | 2.44 | 1.26 | 65.90 | 25.1 | 50.0 |
| Maximum...... | 11.27 | 2.29 | 15.50 | 3.88 | 3.57 | 75.33 | 39.4 | 59.6 |
| Average....... | 9.39 | 1.64 | 12.50 | 3.18 | 1.52 | 71.88 | 33.9 | 58.0 |

The protein of grain sorghums is the most valuable constituent of these grains, although not the most abundant. So far as this substance is concerned, sorghums have a composition approximating that of hard wheat. On the other hand sorghums have somewhat less fiber but more fat than wheat, while the proportion of ash is about

the same in both. Sorghum kernels usually average smaller than wheat kernels and weigh a little less per bushel. The main difference between the composition of sorghum and of wheat lies in the fact that the protein is quite unlike that of wheat. The protein of wheat is chiefly gluten, which possesses the characteristics desirable in bread making, while there is no gluten in the sorghum grain.

An examination of the summary at the end of Table 2 shows that the weight per 1,000 kernels of the milos is considerably greater than that of the other sorghums, while the percentage of fat, ash, and protein is somewhat less. In composition the kafirs and durras lie between the milos and durra kafirs. The durra kafirs are the richest in protein, ash, and fiber, and have the lowest proportion of carbohydrates and the lowest weight per bushel. Kaoliangs, on the other hand, contain appreciably more fat but less fiber than do the other grain sorghums and average the lowest in weight per 1,000 kernels.

When the average compositions of the various grains for each of the five years from 1908 to 1912 are compared the following extremes are shown:

| | Lowest average for one year. | Highest average for one year. |
|---|---|---|
| Water, percent | 9.2 | 10.0 |
| Ash, percent | 1.6 | 2.0 |
| Fat, percent | 3.0 | 4.9 |
| Fiber, percent | 1.2 | 2.0 |
| Protein, percent | 12.1 | 14.9 |
| Carbohydrates, percent | 69.0 | 72.0 |
| Weight per 1,000 kernels, grams | 17.5 | 36.2 |
| Weight per bushel, pounds | 55.1 | 59.2 |

The figures just given are averages for certain years in the series of years. In the case of individual results the actual variation from the minimum to the maximum is much greater, as may be seen from the following figures taken from the summary in Table 2.

| | Minimum. | Maximum. |
|---|---|---|
| Water, percent | 8.02 | 11.27 |
| Ash, percent | 1.33 | 3.06 |
| Protein, percent | 9.19 | 16.75 |
| Fat, percent | 2.22 | 5.36 |
| Fiber, percent | 0.96 | 3.57 |
| Carbohydrates, percent | 65.40 | 75.30 |
| Weight per 1,000 kernels, grams | 13.60 | 39.40 |
| Weight per bushel, pounds | 50.00 | 60.50 |

Table 2 also shows that the sorghum grains are very similar to each other in composition, the widest differences between the average composition of different grains being as follows:

| | Percent. |
|---|---|
| Water | 0.33 |
| Ash | 0.31 |
| Protein | 1.69 |
| Fat | 1.05 |
| Fiber | 0.29 |
| Carbohydrates | 2.80 |

In the case of the weight per 1,000 kernels, however, there is a material difference between the lowest and the highest average, namely, 14.7 grams, while the weight per bushel shows a difference of 2.6 pounds between the lowest and highest average.

Table 3 shows the number of samples analyzed, the average weight per 1,000 kernels, and the average protein content of the various groups of grain sorghums for each year from 1908 to 1912, inclusive. Tables 4, 5, and 6 give comparative determinations for sorghum grains with low and high protein content, low and high weight per 1,000 kernels, and low and high ash content, respectively.

TABLE 3.—*Average percentage of protein and weight per 1,000 kernels of the various grain sorghums grown at Amarillo, Tex., each year from 1908 to 1912.*

| Crop. | 1908. | | | 1909. | | | 1910. | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of samples. | Protein. | Weight per 1,000 kernels. | No. of samples. | Protein. | Weight per 1,000 kernels. | No. of samples. | Protein. | Weight per 1,000 kernels. |
| | | *Percent* | *Grams* | | *Percent* | *Grams* | | *Percent* | *Grams* |
| Milo | 15 | 11.31 | 34.80 | 16 | 13.34 | 36.00 | 22 | 13.43 | 34.35 |
| Kaoliang | 10 | 12.81 | 25.02 | 15 | 13.66 | 18.70 | 12 | 13.87 | 19.89 |
| Kafir | 22 | 12.16 | 24.00 | 38 | 13.62 | 22.23 | 32 | 13.83 | 18.40 |
| Durra | 6 | 12.48 | 26.93 | 15 | 14.03 | 26.80 | 3 | 14.00 | 28.60 |
| Durra kafir | — | — | — | — | — | — | 12 | 14.48 | 21.56 |

| Crop. | 1911. | | | 1912. | | |
|---|---|---|---|---|---|---|
| | No. of samples. | Protein. | Weight per 1,000 kernels. | No. of samples. | Protein. | Weight per 1,000 kernels. |
| | | *Percent* | *Grams* | | *Percent* | *Grams* |
| Milo | 45 | 10.83 | 32.77 | 52 | 13.57 | 33.38 |
| Kaoliang | 25 | 11.88 | 18.44 | 30 | 14.47 | 17.86 |
| Kafir | 42 | 12.49 | 21.98 | 48 | 13.48 | 18.96 |
| Durra | 6 | 12.56 | 29.10 | 9 | 14.19 | 30.50 |
| Durra kafir | 19 | 13.44 | 22.07 | 16 | 14.88 | 23.80 |

A study of Table 3 shows that in the grain sorghums there is no well defined relation between the weight per 1,000 kernels and the protein content, such as one might expect and such as usually exists in the case of wheat. In the milos it would seem that a high protein content is accompanied by a high weight per 1,000 kernels, while with the other sorghums there is a tendency for the opposite to be true, that is, for high protein samples to be those of low weight per 1,000 kernels. In this respect these latter are like wheat, a high weight per 1,000 kernels being correlated with a low protein content. These relations are brought out more clearly in Table 4, where it may also be definitely seen that in most cases high protein samples also contain low fat, high fiber, and high ash. One reason why high weight per 1,000 kernels of milos and of durras is correlated with high protein content would be evident if the bran from these grains were found to contain a lower percentage of protein than the rest of the grain. As large kernels contain relatively less bran, they would be, therefore, in this case relatively richer in protein. In wheat the bran is richer in protein than the rest of the grain and, therefore, high protein wheat usually weighs less than low protein wheat.

TABLE 4.—*Comparison of grain sorghums of low and high protein content, showing average figures for other determinations.*

| Crop and class. | No. of samples. | Protein ($N \times 6.25$). | Water. | Ash. | Fat. | Fiber. | Carbohydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % | *Gm.* | *Lbs.* |
| Milo. | | | | | | | | | |
| Protein less than 10.75 percent...... | 16 | 10.69 | 9.36 | 1.59 | 3.27 | 1.43 | 73.69 | 34.9 | 58.2 |
| Protein more than 13.70 percent..... | 18 | 13.75 | 9.25 | 1.66 | 3.08 | 1.50 | 70.76 | 36.1 | 58.1 |
| Dwarf milo. | | | | | | | | | |
| Protein less than 9.62 percent....... | 14 | 9.56 | 9.48 | 1.54 | 3.37 | 1.39 | 74.65 | 29.8 | 58.8 |
| Protein more than 13.50 percent..... | 14 | 13.56 | 9.57 | 1.67 | 3.23 | 1.53 | 70.48 | 32.1 | 57.7 |
| Brown kaoliang. | | | | | | | | | |
| Protein less than 11.50 percent...... | 17 | 11.44 | 9.35 | 1.84 | 4.17 | 1.27 | 71.96 | 19.0 | 56.7 |
| Protein more than 14.70 percent..... | 18 | 14.75 | 9.88 | 1.95 | 4.07 | 1.50 | 67.94 | 17.7 | 55.2 |
| Blackhull kafir. | | | | | | | | | |
| Protein less than 12.60 percent...... | 19 | 12.56 | 9.45 | 1.66 | 3.53 | 1.58 | 71.30 | 23.1 | 58.7 |
| Protein more than 15.20 percent..... | 19 | 15.25 | 9.60 | 1.85 | 3.44 | 1.57 | 68.22 | 20.8 | 58.1 |
| Red kafir. | | | | | | | | | |
| Protein less than 11.20 percent...... | 15 | 11.13 | 9.92 | 1.60 | 3.12 | 1.44 | 72.80 | 21.5 | 58.6 |
| Protein more than 13.70 percent..... | 16 | 13.75 | 9.82 | 1.79 | 3.22 | 1.46 | 69.96 | 20.5 | 57.9 |
| Durra and durra kafir. | | | | | | | | | |
| Protein less than 12.46 percent...... | 10 | 11.90 | 9.55 | 1.87 | 3.57 | 1.39 | — | 24.4 | 57.0 |
| Protein more than 14.60 percent..... | 13 | 15.08 | 9.08 | 1.95 | 3.58 | 1.63 | — | 23.7 | 55.5 |

That a large kernel is often correlated with a low fiber content is due to the fact that large kernels have relatively less superficial area

than small and consequently less bran, in which the greater part of the fiber is found. A grain with low weight per 1,000 kernels being smaller and having a relatively large surface or coating will be higher in fiber than one having a higher kernel weight. It may also be higher in protein if the bran has a high protein content, as is true of most cereals, especially wheat, rye, oats, and barley. Low protein in the grain sorghums is, on the other hand, correlated with high weight per bushel, low fiber, low ash, and low pentosans, and, except in the case of milos, with low weight per 1,000 kernels.[5]

The above conclusions were drawn after comparing the average composition of a number of samples containing the least amount of protein with a number containing the greatest amount of protein.

TABLE 5.—*Comparison of grain sorghums of low and high weight per 1,000 kernels, showing average figures for other determinations.*

| Crop and class. | No. of samples. | Weight per 1,000 kernels. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| | | *Gm.* | % | % | % | % | % | *Lbs.* |
| Milo. | | | | | | | | |
| Wt. of 1,000 kernels less than 30.2 grams .. | 12 | 28.2 | 9.16 | 1.65 | 11.33 | 3.26 | 1.53 | 57.7 |
| Wt. of 1,000 kernels more than 37.9 grams. | 11 | 38.7 | 9.64 | 1.52 | 11.90 | 3.31 | 1.51 | 58.3 |
| Kaoliang. | | | | | | | | |
| Wt. of 1,000 kernels less than 16.6 grams .. | 11 | 15.4 | 8.90 | 1.95 | 12.70 | 4.18 | 1.46 | 55.8 |
| Wt. of 1,000 kernels more than 23.4 grams. | 11 | 25.4 | 8.94 | 1.82 | 12.90 | 4.27 | 1.29 | 56.4 |
| Kafir. | | | | | | | | |
| Wt. of 1,000 kernels less than 16.9 grams .. | 13 | 15.5 | 9.18 | 1.70 | 12.57 | 3.25 | 1.63 | 57.2 |
| Wt. of 1,000 kernels more than 26.3 grams. | 9 | 28.1 | 9.48 | 1.65 | 12.61 | 3.36 | 1.38 | 58.4 |
| Durra kafir. | | | | | | | | |
| Wt. of 1,000 kernels less than 21.0 grams .. | 12 | 19.7 | 9.08 | 1.92 | 13.62 | 3.64 | 1.63 | 57.1 |
| Wt. of 1,000 kernels more than 28.0 grams. | 10 | 32.7 | 9.40 | 1.70 | 13.22 | 3.22 | 1.45 | 55.7 |

From a consideration of the results given in Table 5 it would seem that samples having a high weight per 1,000 kernels are those which contain low fiber and low ash. This table also shows that there is no definite relation between the weight per 1,000 kernels and the protein content. From Table 6 it will be seen that low ash is accompanied by low protein, low fiber, high weight per 1,000 kernels, and high weight per bushel. There is, however, no such correlation between ash and fat content.

[5] The pentosans were not determined in all samples and consequently the results are not recorded here. The amount of pentosans in the samples analyzed for this constituent varies from 2.35 to 4.69, with an average of 3.89. High pentosan content is accompanied by high fiber, high ash, high protein, and low weight per 1,000 kernels in all the groups except the milos, where high pentosan samples have low fiber, low ash, low protein, and high weight per 1,000 kernels.

TABLE 6.—*Comparison of grain sorghums of low and high ash content, showing average figures for other determinations.*

| Crop and class. | No. of samples. | Ash. | Protein ($N \times 6.25$). | Water. | Fat. | Fiber. | Weight per 1,000 kernels. | Weight per bushel |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | *Gm.* | *Lbs.* |
| Milo. | | | | | | | | |
| Ash less then 1.47 percent | 10 | 1.42 | 10.91 | 9.78 | 3.32 | 1.51 | 35.1 | 58.8 |
| Ash more than 1.77 percent | 12 | 1.81 | 13.51 | 8.66 | 3.03 | 1.68 | 32.5 | 57.2 |
| Kaoliang. | | | | | | | | |
| Ash less than 1.70 percent | 10 | 1.62 | 12.63 | 8.95 | 4.47 | 1.26 | 19.2 | 57.5 |
| Ash more than 2.05 percent | 9 | 2.13 | 13.47 | 8.80 | 4.23 | 1.40 | 18.8 | 55.2 |
| Kafir. | | | | | | | | |
| Ash less than 1.59 percent | 11 | 1.55 | 12.01 | 9.72 | 3.30 | 1.49 | 23.6 | 58.5 |
| Ash more than 1.90 percent | 11 | 1.94 | 14.85 | 9.36 | 3.58 | 1.65 | 20.7 | 57.1 |
| Durra kafir. | | | | | | | | |
| Ash less than 1.71 percent | 11 | 1.59 | 12.60 | 9.26 | 3.45 | 1.32 | 29.1 | 57.2 |
| Ash more than 2.00 percent | 12 | 2.06 | 14.55 | 8.66 | 3.62 | 1.73 | 22.0 | 54.7 |

Two of the less extensively grown sorghums are broomcorn and shallu. The figures given in Table 7 show the composition of a small number of samples of seed of these crops grown at Amarillo, Tex., during the years 1911 and 1912. It will be noted that the samples from the crops grown in 1911 were considerably lower in protein, ash, and fiber, but somewhat higher in fat and in carbohydrates than were those grown in 1912.

TABLE 7.—*Composition of broomcorn and shallu grown at Amarillo, Tex.*

| Name. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Carbo-hy-drates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Grams* | *Pounds* |
| Broomcorn. | | | | | | | | |
| 1911, 5 samples. | | | | | | | | |
| Minimum | 10.05 | 2.56 | 11.94 | 3.43 | 3.40 | 65.66 | 14.7 | 50.3 |
| Maximum | 10.72 | 3.02 | 12.81 | 3.85 | 4.39 | 67.82 | 16.3 | 53.9 |
| Average | 10.52 | 2.85 | 12.44 | 3.66 | 3.96 | 66.54 | 15.1 | 51.6 |
| 1912, 9 samples. | | | | | | | | |
| Minimum | 9.36 | 2.84 | 12.44 | 2.95 | 4.17 | 62.24 | 11.4 | 42.6 |
| Maximum | 9.83 | 3.60 | 15.94 | 3.56 | 6.58 | 66.49 | 16.4 | 51.4 |
| Average | 9.62 | 3.16 | 14.63 | 3.34 | 5.54 | 63.62 | 13.9 | 48.5 |
| Shallu. | | | | | | | | |
| 1911, 4 samples. | | | | | | | | |
| Minimum | 10.74 | 1.84 | 12.88 | 3.51 | 1.65 | 67.42 | 14.0 | 58.5 |
| Maximum | 10.98 | 1.91 | 14.13 | 4.13 | 1.80 | 68.97 | 17.0 | 59.6 |
| Average | 10.85 | 1.88 | 13.31 | 3.72 | 1.74 | 68.48 | 14.9 | 58.9 |
| 1912, 6 samples. | | | | | | | | |
| Minimum | 9.68 | 1.94 | 16.13 | 3.19 | 1.86 | 65.38 | 14.7 | 52.2 |
| Maximum | 10.76 | 2.37 | 16.69 | 4.02 | 2.62 | 66.15 | 15.9 | 58.5 |
| Average | 10.07 | 2.05 | 16.44 | 3.67 | 2.05 | 65.75 | 15.3 | 57.2 |

It would seem from a study of Table 7 that the weight per 1,000 kernels of shallu was not influenced either by the abundant rainfall at Amarillo during 1911 (16.44 inches from April to ripening), or by the scanty rainfall in 1912 (10.68 inches). In the case of the broom-corn, however, a slight decrease in weight per 1,000 kernels in 1912 may have been the result of a dry season. The protein content, however, was materially affected by a lack of rainfall in that year.

From a consideration of the data in Table 8, it is impossible to state whether the low protein in the grains of 1908 and 1911 was due to the high annual rainfall, to the high rainfall from April to the ripening period, or to the rainfall from April up to the period of emergence. Although the experiments discussed in this paper have been carried on for five years and with a large number of varieties of sorghums, the data obtained are not sufficient to reveal the reason for the low percentage of protein in the grains during the two years, 1908 and 1911. It is necessary, apparently, to obtain similar data not only for a number of years and with a number of crops, but in a number of different localities.

Because in the years 1908 and 1911 many more pounds of protein were produced per acre than in the years 1909, 1910, and 1912, and because in 1908 and 1911 there were very copious rains before the period of emergence, it may be concluded that this large amount of rainfall gave the plants a propitious start, allowing them to become well developed and capable of bearing large crops. During a season of high and favorable rainfall the yield is much increased, but the crop contains a relatively low percentage of protein.

Table 8 gives the total rainfall from April to the ripening period, and also the rainfall from April to emergence, from emergence to heading, and from heading to ripening. This table also gives the yield per acre in bushels and in pounds, the percentage of protein, and the yield of protein per acre in pounds. The figures show that in 1908 and 1911 the largest yields were obtained; that these crops contained the smallest percentage of protein; that notwithstanding the low percentage of protein the number of pounds of protein per acre was much greater than in the other three years; that the greatest amount of rain fell in 1908 and 1911; and that the amount of rain falling before the period of emergence was considerably larger in these years than in other years.

TABLE 8.—*Rainfall at various periods during the growth of various grain sorghums at Amarillo, Tex., annually from 1908 to 1912, with the yield of grain and of protein per acre each year.*

| Crop and year. | Protein. | Rainfall. Total, April to ripening.[a] | Rainfall. April to emergence. | Rainfall. Emergence to heading. | Rainfall. Heading to ripening. | Yield of grain per acre. | | Yield of protein per acre. |
|---|---|---|---|---|---|---|---|---|
| | % | *Inches* | *Inches* | *Inches* | *Inches* | *Bu.* | *Lbs.* | *Lbs.* |
| Milo, | | | | | | | | |
| 1908 | 11.31 | 15.12 | 5.35 | 7.88 | 2.75 | 35.62 | 2,053 | 232.2 |
| 1909 | 13.44 | 12.99 | 1.56 | 8.58 | 2.92 | 6.14 | 355 | 47.7 |
| 1910 | 13.44 | 10.00 | 3.37 | 3.11<br>5.58 [b] | 2.96 | 19.67 | 1,143 | 153.6 |
| 1911 | 11.13 | 16.20 | 8.55 | 3.93 | 3.22 | 32.28 | 1,890 | 210.4 |
| 1912 | 13.63 | 9.16 | 2.17 | 5.01 | 1.76 | 18.97 | 1,107 | 151.0 |
| Dwarf milo, | | | | | | | | |
| 1908 | 11.31 | 15.12 | 5.35 | 7.88 | 2.75 | 41.37 | 2,388 | 270.0 |
| 1909 | 13.13 | 12.99 | 1.56 | 8.58 | 2.92 | 11.00 | 638 | 83.8 |
| 1910 | 13.13 | 10.00 | 3.37 | 3.11<br>5.58 [b] | 2.96 | 20.68 | 1,190 | 156.3 |
| 1911 | 10.13 | 16.20 | 8.55 | 3.93 | 3.22 | 38.24 | 2,240 | 227.0 |
| 1912 | 13.31 | 9.16 | 2.17 | 5.80 | 1.76 | 22.64 | 1,318 | 175.4 |
| White durra, | | | | | | | | |
| 1908 | 12.63 | 16.12 | 6.11 | 5.11<br>8.65 [b] | 5.83<br>6.57 [c] | 33.29 | 1,870 | 236.2 |
| 1909 | 14.06 | 12.99 | 1.76 | 8.23<br>8.90 [b] | 0.76<br>2.92 [c] | 11.51 | 647 | 91.0 |
| 1910 | 14.00 | 10.06 | 3.46 | 3.11<br>4.62 [b] | 2.96 | 10.60 | 602 | 84.3 |
| 1911 | 12.56 | 16.62 | 8.55 | 3.83 | 2.81 | 32.44 | 1,840 | 231.0 |
| 1912 | 14.19 | 11.31 | 2.17 | 4.97<br>5.76 [b] | 1.66<br>3.81 [c] | 19.17 | 1,084 | 153.3 |
| Brown kaoliang, | | | | | | | | |
| 1908 | 12.75 | 17.16 | 5.35 | 7.88 | 2.75<br>4.37 [c] | 29.71 | 1,675 | 213.5 |
| 1909 | 13.75 | 11.47 | 1.77 | 7.43<br>8.92 [b] | 3.65 | 13.04 | 738 | 101.5 |
| 1910 | 13.75 | 10.00 | 3.47 | 2.27<br>4.78 [b] | 4.70<br>5.33 [c] | 10.45 | 583 | 80.2 |
| 1911 | 11.94 | 16.61 | 8.44 | 3.93 | 2.81<br>3.22 [c] | 22.09 | 1,244 | 148.5 |
| 1912 | 14.44 | 11.24 | 2.15 | 3.12<br>6.67 [b] | 4.02<br>6.11 [c] | 11.70 | 649 | 93.6 |
| Blackhull kaoliang, | | | | | | | | |
| 1908 | 12.44 | 17.16 | 5.35 | 7.88 | 3.49<br>4.37 [c] | 43.10 | 2,370 | 295.0 |
| 1909 | 13.25 | 12.99 | 1.77 | 8.92 | 2.82 | 9.44 | 544 | 72.1 |
| 1910 | 13.81 | 10.05 | 3.47 | 3.95<br>6.07 [b] | 2.96 | 6.92 | 384 | 53.3 |
| 1911 | 11.25 | 16.20 | 8.44 | 3.93 | 3.22 | 25.40 | 1,465 | 164.8 |
| 1912 | 14.75 | 11.24 | 2.15 | 6.67 | 2.15 | 15.93 | 902 | 132.7 |

| Crop and year. | Protein. | Rainfall. Total, April to ripening.[a] | Rainfall. April to emergence. | Rainfall. Emergence to heading. | Rainfall. Heading to ripening. | Yield of grain per acre. | | Yield of protein per acre. |
|---|---|---|---|---|---|---|---|---|
| | % | *Inches* | *Inches* | *Inches* | *Inches* | *Bu.* | *Lbs.* | *Lbs.* |
| Blackhull kafir, | | | | | | | | |
| 1908 | 12.63 | 16.50 | 5.16 | 8.09<br>8.86 [b] | 2.72<br>2.95 [c] | 33.82 | 1,975 | 249.5 |
| 1909 | 14.75 | 12.99 | 1.56 | 9.01 | 2.16 | 5.04 | 294 | 43.3 |
| 1910 | 14.56 | 10.07 | 3.47 | 4.80<br>6.07 [b] | 1.45 | 9.66 | 555 | 80.8 |
| 1911 | 13.38 | 16.62 | 8.55 | 6.62 | 0.95 | 21.24 | 1,210 | 162.0 |
| 1912 | 14.44 | 11.31 | 2.19 | 6.27 | 2.15 | 4.09 | 238 | 34.3 |
| Red kafir, | | | | | | | | |
| 1908 | 11.31 | 16.50 | 5.26 | 8.86 | 3.10 | 33.05 | 1,960 | 221.7 |
| 1909 | 12.50 | 12.99 | 1.56 | 9.01 | 2.16 | 3.81 | 224 | 28.0 |
| 1910 | 12.31 | 10.07 | 3.47 | 5.81 | 0.35 | 5.21 | 300 | 36.9 |
| 1911 | 11.56 | 16.62 | 8.55 | 6.62 | 0.95 | 18.68 | 1,090 | 126.0 |
| 1912 | 12.94 | 11.31 | 2.19 | 6.27 | 2.15 | 4.26 | 246 | 31.8 |
| Average, | | | | | | | | |
| 1908 | 12.05 | 16.24 | 5.42 | 7.51<br>8.27 [b] | 3.34<br>3.81 [c] | 35.71 | 2,041 | 245.4 |
| 1909 | 13.55 | 12.77 | 1.65 | 8.54<br>8.84 [b] | 2.55<br>2.80 [c] | 8.57 | 493 | 66.8 |
| 1910 | 13.57 | 10.04 | 3.44 | 3.74<br>5.49 [b] | 2.62<br>2.74 [c] | 11.88 | 680 | 91.1 |
| 1911 | 11.71 | 16.44 | 8.30 | 4.68 | 2.45<br>2.52 [c] | 27.19 | 1,568 | 181.4 |
| 1912 | 13.96 | 10.68 | 2.17 | 5.44<br>6.06 [b] | 2.23<br>2.84 [c] | 13.40 | 795 | 110.3 |

[a] The total rainfall from harvest to harvest is approximately as follows: 1907–08, 20.3 inches; 1908–09, 16.6 inches; 1909–10, 15.5 inches; 1910–11, 20.3 inches; and 1911–12, 14.8 inches.

[b] The heading was irregular. The top figures indicate the rainfall up to the first appearance of heads; the lower figures show the rainfall to the end of heading.

[c] The ripening was irregular. The top figures indicate the rainfall from beginning of heading to beginning of ripening. The lower figures show the rainfall from beginning of heading to end of ripening.

From Table 8 it appears that the amount of rain falling between the period of emergence and heading, or between the period of heading and ripening, did not exert so much influence upon the composition or yield as did the early rainfall or the total rainfall. For example, in every case where there was a heavy early and total rainfall, the yield was very large and the percentage of protein was relatively small. On the other hand, for the rainfall between the periods of emergence and heading no such regularity is noted. For example, milo, dwarf milo, brown kaoliang, blackhull kafir, and red kafir had a

high percentage of protein in 1909, and yet the rainfall between the periods of emergence and heading was practically the same as in 1908 when these same sorghums contained a low percentage of protein. In the same way milo, dwarf milo, white durra, and blackhull kaoliang in 1911 contained low percentages of protein and in 1910 high percentages of protein, although in these years the total rainfall between the periods of heading and ripening was almost identical. From the results obtained in these particular cases it is evident, therefore, that the amount of rainfall between the periods of emergence and ripening has less influence upon the composition and yield of the crop than has either the amount of rainfall before the period of emergence or the total yearly rainfall.

In Table 9 the average analyses of the grain sorghums are given. For comparison, average analyses of other grains and seeds grown generally throughout the United States are also given in this table.

TABLE 9.—*Average composition of the various grain sorghums at Amarillo, Tex., 1908–1912, with the composition of various grains and seeds grown widely throughout the United States for comparison.*

| Crop. | No. of samples. | Water. | Ash. | Protein ($N \times 6.25$). | Fat. | Fiber. | Carbohydrates. | Weight per 1,000 kernels. | Weight per bushel. |
|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % | *Gm.* | *Lbs.* |
| Durra | 39 | 9.50 | 1.73 | 13.63 | 3.47 | 1.49 | 70.30 | 28.2 | 56.7 |
| Durra kafir | 47 | 9.61 | 1.95 | 14.19 | 3.51 | 1.65 | 69.08 | 22.3 | 55.6 |
| Kafir | 182 | 9.70 | 1.76 | 13.13 | 3.30 | 1.54 | 70.30 | 20.7 | 58.2 |
| Kaoliang | 92 | 9.37 | 1.87 | 13.37 | 4.23 | 1.36 | 69.84 | 19.2 | 56.3 |
| Milo | 150 | 9.39 | 1.64 | 12.50 | 3.18 | 1.52 | 71.88 | 33.9 | 58.0 |
| Shallu | 10 | 10.36 | 1.98 | 15.19 | 3.69 | 1.93 | 66.84 | 15.1 | 57.9 |
| Broomcorn | 14 | 9.93 | 3.05 | 13.44 | 3.45 | 4.98 | 64.66 | 14.3 | 49.6 |
| Maize[a] | 114 | 10.04 | 1.55 | 10.39 | 5.20 | 2.09 | 70.69 | 367.4 | — |
| Wheat[b] | 166 | 10.62 | 1.82 | 12.23 | 1.77 | 2.36 | 71.18 | 38.6 | 60.4 |
| Oats | 133 | 7.10 | 3.50 | 14.87 | 4.52 | 10.10 | 59.91 | 22.9 | — |
| Barley | 84 | 8.71 | 2.98 | 11.86 | 2.02 | 5.76 | 68.98 | 39.2 | — |
| Rye[b] | 57 | 8.67 | 2.09 | 11.32 | 1.94 | 1.46 | 74.52 | 20.7 | — |
| Emmer | 41 | 8.50 | 4.00 | 13.94 | 1.95 | 8.44 | 63.17 | 29.6[c] | — |
| Einkorn[d] | 4 | 8.34 | 5.57 | 14.67 | 2.19 | 13.55 | 55.68 | — | — |
| Proso | 43 | 9.12 | 2.90 | 13.54 | 3.52 | 7.38 | 63.54 | 5.3 | — |
| Millet | 13 | 9.28 | 3.47 | 14.56 | 4.17 | 8.25 | 60.27 | 1.8 | — |
| Buckwheat | 31 | 9.38 | 2.05 | 12.00 | 2.47 | 10.11 | 63.99 | 27.9 | — |
| Rice (hulled) | 97 | 10.61 | 1.25 | 6.75 | 2.35 | .85 | 78.19 | 23.7 | — |
| Soybeans | 33 | 7.29 | 5.19 | 38.94 | 18.14 | 4.24 | 26.20 | 154.0 | — |
| Cowpeas | 16 | 8.84 | 3.79 | 23.26 | 1.25 | 4.47 | 58.39 | 147.0 | — |
| Beans (adzuki) | 13 | 10.01 | 3.41 | 23.56 | .43 | 4.11 | 58.48 | 87.0 | — |
| Flax | 64 | 5.31 | 3.67 | 27.00 | 35.13 | 5.09 | 23.80 | 4.0 | — |

[a] U. S. Dept. Agr., Bur. Chem. Bul. 50. 1898.
[b] U. S. Dept. Agr., Bur. Chem. Bul. 45. 1895.
[c] Without hulls.
[d] U. S. Dept. Agr., Bur. Chem. Bul. 120. 1909.

### SUMMARY.

The minimum and maximum results obtained and the average composition found in analyses of several hundred samples of grain sorghums grown at Amarillo, Tex., from 1908 to 1912, are given.

The results have been arranged in tabular form so as to bring out the correlations between the percentage of protein and the weight per 1,000 kernels; and also to show how the composition of grain varies with

(1) a high and low protein content,
(2) a high and low weight per 1,000 kernels, and
(3) a high and low ash content.

There is also an attempt made to correlate the protein content and the yield with the rainfall.

Analyses of shallu and broomcorn are given and also of bread made in part from grain sorghum meal.

The composition of the grain sorghums is compared with that of many other grains and seeds.


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# THE EFFECT OF GREENHOUSE TEMPERATURES ON THE GROWTH OF SMALL GRAINS.[1]

T. B. Hutcheson and K. E. Quantz.

During the past few years it has been a common practice at some of the experiment stations to grow small grains in greenhouses for breeding work, for pot tests of soils, and for other similar experiments. For the crossing of varieties and the rapid increase of selected seed of small grains, the greenhouse offers almost invaluable aid, as by its use two crops of most of the grains may be grown in one year. Greenhouses are also usually more conveniently located than field plots and are therefore more accessible to the workers.

When the crops are grown at the proper temperatures they set seed well and hand pollination may be practiced very successfully. It is not at all difficult to get 80 percent or more of all crosses made to set seed when the work is done carefully. For crossing it is usually best to grow the plants in small pots, as these may be placed in any convenient position for working and may be segregated easily after the cross is made, either by placing them in another apartment or by separating them from other plants by canvas partitions.

Failures to get small grains to set seed properly in greenhouses are often reported, however. The writers believe that such failures are often due to the maintenance of improper temperatures in the houses. For this reason an experiment was conducted during the winter of 1915 to test the effect of temperature upon the growth of winter wheat, oats, barley, and rye grown in the greenhouse.

Fulcaster wheat, Culberson oats, Union Winter barley, and Abruzzes rye were used in this experiment. The seeds of these grains were sown in 4-inch clay pots. The pots were divided into four groups. Each group consisted of four series of four pots each, one series of each of the grains under test. Each group was placed in a different greenhouse. The greenhouses were kept as near as possible to the following temperatures: House No. 1, 75° F.; house No. 2, 65° F.; house No. 3, 62° F.; and house No. 4, 58° F. Owing to the great variation of the outdoor temperature it was found impossible to keep the temperatures in the houses from fluctuating widely. This was

[1] Paper No. 3 from the Department of Agronomy, Virginia Polytechnic Institute and Agricultural Experiment Station. Received for publication October 25, 1916.

particularly true during April and May, when the days became longer and warmer. The curves (figure 1) illustrating the average weekly temperature of the houses show this variation. It will be noticed that there was always a difference in the temperatures of the houses, though it was impossible under our conditions to keep the temperatures as regular as desired.

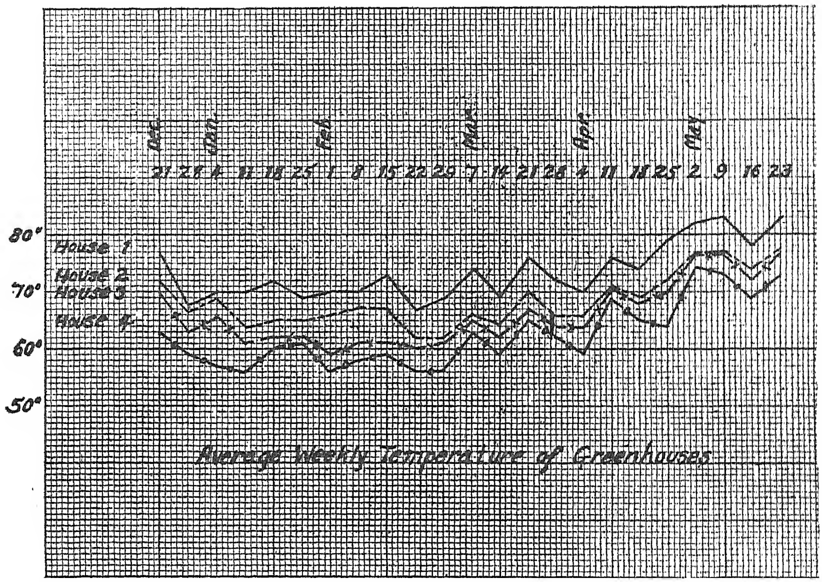


FIG. 1. Average weekly temperature of the four greenhouses from December 27 to May 23.

The seeds were sown and the pots were placed in their respective houses on December 21, 1915. Several seeds were sown in each pot and all pots were thinned to two plants as soon as the plants were well up. Notes were taken on the growth as often as it was thought necessary. The data thus recorded are given in Table 1. On May 27 the experiment was discontinued on account of the extreme heat in the houses. The tillers recorded in Table 1 include only those that were still green on that date. The length of culms is the average length of all tillers which produced heads. The tillers which had not headed were not measured.

There are some very striking features in the results of this experiment. In the first place, the time of heading, blooming, and ripening of the different grains varied considerably in the different houses. The order of maturity was sometimes almost reversed. Thus, oats

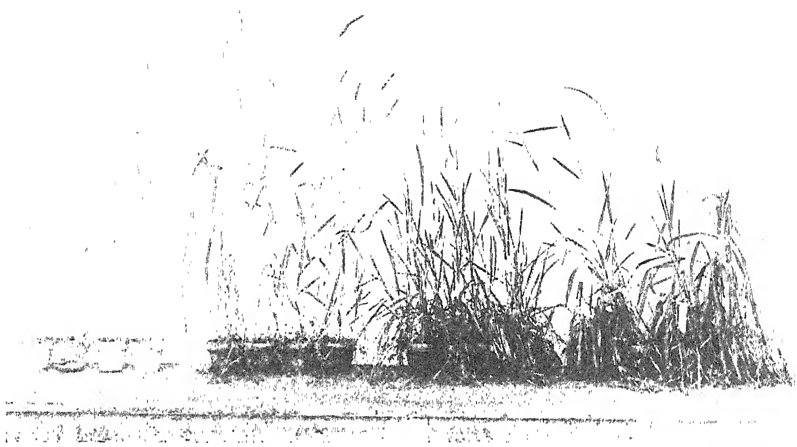

FIG. 1. Wheat grown in greenhouses kept at different temperatures; from left to right, grown at temperatures of 58, 62, 65, and 75° F., respectively.

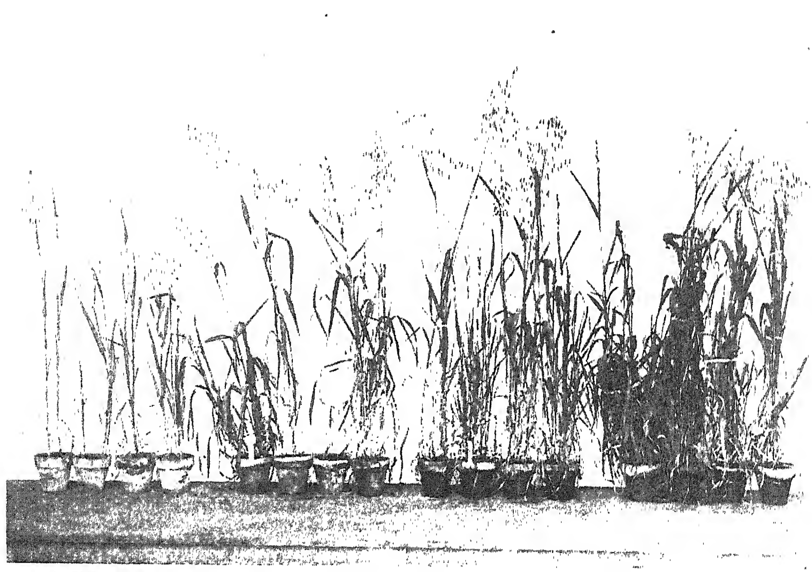

FIG. 2. Oats grown in greenhouses kept at different temperatures; from left to right, grown at temperatures of 58, 62, 65, and 75° F., respectively.

FIG. 1. Barley grown in greenhouses kept at different temperatures; from left to right, grown at temperatures of 58, 62, 65, and 75° F., respectively.

FIG. 2. Rye grown in greenhouses kept at different temperatures; from left to right, grown at temperatures of 58, 62, 65, and 75° F., respectively.

was the first grain to head in the hottest house, while in the coolest house the rye was first to head, the oats heading last. In the second warmest house the results were somewhat similar to those in the first house, but were slightly modified. Here also the oats headed before the rye.

TABLE 1.—*Data on growth of wheat, oats, barley, and rye in greenhouses kept at various temperatures.*

| House No. | Temperature (°F.). | Dates of —. | | | | Number per plant. | | Average length, inches. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Emergence. | Heading. | Blooming. | Ripening. | Tillers. | Heads. | Culms. | Heads. |
| | | | | WHEAT. | | | | | |
| 1 | 75 | Dec. 28 | May 10–27 | May 13–27 | — | 8.75 | 0.87 | 35.05 | 4.24 |
| 2 | 65 | do. | May 15 | May 20 | — | 8.00 | 1.75 | 31.48 | 3.28 |
| 3 | 62 | do. | Apr. 26 | Apr. 29 | May 27 | 5.37 | 3.00 | 45.05 | 4.38 |
| 4 | 58 | Dec. 31 | May 2 | May 3 | — | 1.25 | 1.12 | 36.74 | 3.68 |
| | | | | OATS. | | | | | |
| 1 | 75 | Dec. 29 | Apr. 17 | Apr. 26 | May 24–27 | 9.00 | 4.62 | 30.46 | 7.13 |
| 2 | 65 | do. | do. | do. | do. | 5.62 | 3.50 | 32.12 | 8.75 |
| 3 | 62 | do. | Apr. 25 | Apr. 29 | May 27 | 3.37 | 2.00 | 34.54 | 8.00 |
| 4 | 58 | Dec. 31 | May 1 | May 5 | — | 1.50 | 1.29 | 30.46 | 7.70 |
| | | | | BARLEY. | | | | | |
| 1 | 75 | Dec. 29 | — | — | — | 48.25 | — | — | — |
| 2 | 65 | do. | May 25 | May 26 | — | 23.87 | — | — | — |
| 3 | 62 | do. | May 16 | May 17 | — | 8.00 | 1.12 | 21.29 | 2.00 |
| 4 | 58 | Dec. 31 | May 2 | May 5 | — | 1.75 | 1.75 | 23.42 | 2.38 |
| | | | | RYE. | | | | | |
| 1 | 75 | Dec. 28 | Apr. 25–May 27 | May 3–27 | — | 29.25 | 1.12 | 31.30 | 4.64 |
| 2 | 65 | do. | Apr. 29 | May 1 | — | 5.00 | 1.62 | 40.65 | 4.25 |
| 3 | 62 | do. | Apr. 18 | Apr. 25 | May 27 | 5.37 | 3.00 | 45.05 | 4.38 |
| 4 | 58 | Dec. 31 | Apr. 17 | May 2 | — | 1.00 | 1.00 | 60.31 | 4.88 |

The wheat stood the warm temperature only a little better than the rye. It did not tiller as much and produced stronger heads, but otherwise there was little difference. In the cool houses the wheat did well—about like it does under ordinary field conditions. Each plant produced from one to several heads, all well filled, which ripened very uniformly. The pots of wheat from the houses kept at different temperatures are shown in Plate 1, figure 1.

The oats appeared to be affected least of all by variations in temperature. The most notable effect was that in the warmer houses

the plants grew more rapidly and the culms were weaker, necessitating tying up the plants. The plants were taller in the warm houses and produced more leaves and stalks (Plate 1, fig. 2). There was no harmful effect of a serious nature due to heat up to 80° F. The same fact was observed a few years ago at the Maryland station by the junior author. There the oats grew in a hot greenhouse to a height of 5 or 6 feet, while the wheat and barley did not head out.

The barley showed most strikingly the difference between warm and cool temperatures. In the cool house the barley was almost ripe when the experiment was brought to a close and fully ripe three days later. In the warmest house it had produced only an enormous mass of tillers and there were no indications that it would ever head. Plate 2, figure 1, shows this condition clearly. In the second warmest house the barley did slightly better, but at the close of the experiment had made no start toward heading. In the second coolest house the barley had not tillered excessively but it was considerably behind that in the coolest house in development.

The rye evidently does best at the lower temperatures. It was best in the coldest house at the time the experiment was concluded. Each rye plant in this house produced one long, well-filled ear of grain, while in house No. 3 the rye produced more heads, but they were not nearly so well filled with grain. In houses No. 1 and No. 2 the rye did not do well at all. It seems to have wasted all of its energy in producing a great mass of tillers that crowded each other so that there was no chance for development. The heads were slender and showed little indication of grain production. The time of ripening was delayed at least several weeks, and stretched out over a long period. The rye plants from the various houses are shown in Plate 2, figure 2.

The results of this experiment show the effects of temperature in the following ways:

1. Except in the case of oats, a cool temperature seems to produce earlier maturity, while high temperature stimulates a rank growth of tillers and thus wastes energy needed for the formation of heads.

2. Barley is affected by heat, while wheat and rye also suffer considerably, though not as much as barley. Oats show very little ill effect from high temperature. This would indicate that they are better for soil work in greenhouses where temperature cannot be controlled closely.

3. The setting of seed is best in the cooler houses, except with oats, which show no difference in this respect.

4. The tillering was greatest in the warmer temperatures and least in the cool houses, but the difference in the number of heads is overcome by the large percentage of seed produced per head, except with oats.

5. It is advisable to grow grain at a moderately cool temperature in the greenhouse. From 55° to 70° F. seems to be about the proper temperature.

VIRGINIA POLYTECHNIC INSTITUTE,
BLACKSBURG, VA.

# THE RELATION OF WINTER TEMPERATURE TO THE DISTRIBUTION OF WINTER AND SPRING GRAINS IN THE UNITED STATES.[1]

S. C. SALMON.

The successful culture of winter grains in northern latitudes depends largely on winter temperature. As, however, many other factors may determine whether a farmer sows winter or spring grain where both may be successfully grown, the distribution of winter cereals in relation to temperature is of general interest. The census reports and weather bureau records of the United States and Canada afford excellent material for studying this relation. Such a study was begun during the winter of 1913–14 and has since been continued at intervals. The maps (figs. 2 and 3) show the results obtained with winter and spring wheat. The distribution in the United States was plotted by counties on the basis of the census returns for 1909. The distribution in Canada is based largely on the cereal maps published by the Canadian Department of the Interior in 1909. The acreage for Canada is for 1911. The isotherms connect points of equal daily minimum temperature for January and February, the coldest months of the year.

The isotherm of 10° F. daily minimum temperature coincides remarkably well with the northern boundary of winter wheat culture if this boundary is taken as the line beyond which spring wheat is grown more commonly than winter wheat. The correlation is so close, in fact, that in general the isotherm divides the winter from the spring wheat belt. There are some exceptions to this statement, but it is

[1] Contribution from the Kansas Agricultural Experiment Station. Received for publication October 18, 1916.

perhaps significant that in nearly every case spring wheat is grown south of the isotherm rather than winter wheat north of it. This would be expected, since it is possible to grow spring grain wherever winter grain is a success, but the converse is not true.

There are several reasons why spring wheat is sometimes grown where winter wheat is produced successfully. In Washington, for example, late harvest of spring oats and barley prevents timely preparation of the ground for winter wheat. Many farmers who are growing wheat exclusively find that they can sow and care for a larger acreage if they grow both winter and spring varieties than if they grow either exclusively. Spring wheat is sometimes preferred to winter wheat where corn is the main crop, since it is often difficult to get a good stand of winter wheat after corn. In western Kansas and eastern Colorado the lack of sufficient fall rain to insure germination often prevents the growing of winter wheat where it would otherwise be successful.

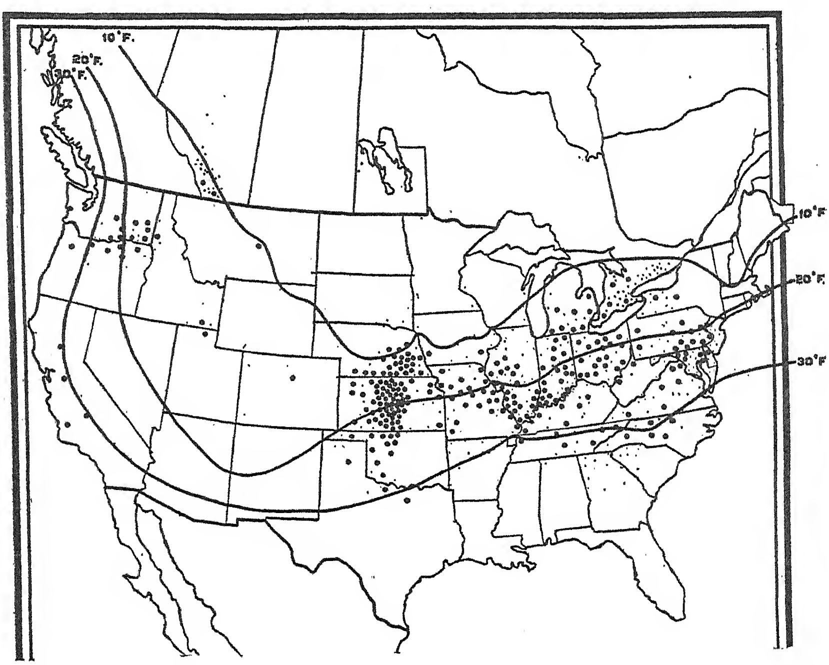


FIG. 2. Distribution of winter wheat in the United States and Canada. Each large dot represents 100,000 acres and each small dot, 5,000 acres. The isothermal lines connect points of equal mean daily temperature during January and February.

The change from spring to winter wheat when it is fully demonstrated that the latter is best is generally rather slow, due to conservative markets and prejudice on the part of grower and buyer. For many years hard winter wheat sold at a discount as compared with either spring wheat or soft winter wheat. In certain localities west of the Rocky Mountains at the present time the hard winter varieties, Turkey and Kharkof, sell at a discount.

Small acreages of winter wheat are grown in central and northern Minnesota and Wisconsin and in southeastern South Dakota. Special methods of culture, as seeding in corn stalks, or special conditions, as a heavy covering of snow, usually are necessary for its successful production.

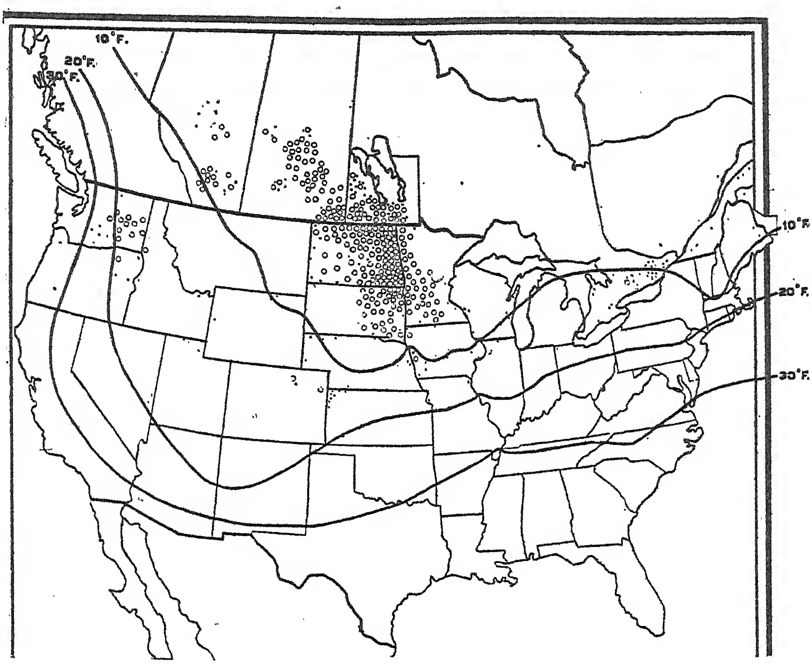


FIG. 3. Distribution of spring wheat in the United States and Canada. The circles represent 100,000 acres each and the dots, 5,000 acres. Isothermal lines connect points of equal mean daily minimum temperatures for January and February.

The isotherms of 20° and 30° coincide very closely with the northern limits for winter barley and winter oats respectively, so far as our knowledge of the climatic limits of these crops allow conclusions.

Winter barley, according to Derr,[2] is confined to the states south of the Ohio and Platte rivers and west of the Rocky Mountains. At Manhattan, Kans., winter barley survives sufficiently to produce a good crop about four years out of five. Stephens states that it is grown extensively in Oregon only in Wasco and Umatilla counties in the Columbia River basin.[3] The data are not sufficient to show the northern limit of this crop, but it apparently bears a close relation to the daily minimum winter temperature as shown by the isotherm of 20° F.

Warburton[4] shows by means of a shaded map the area in the United States adapted to winter oats as indicated by general observation and by experiments. He recommends them for as far north as southern Maryland, central Tennessee, central Arkansas, and southern Oklahoma, and states that they are grown to a limited extent in Utah, Oregon, and Washington. There is almost perfect agreement between the northern limit of the culture of this cereal in the eastern United States, as shown by this map, and the isotherms of 30° F., as shown in figures 2 and 3.

The absence of any correlation between the northern limit of winter cereal culture and snowfall is surprising. In the eastern United States, for example, where the snowfall is much greater than in central Nebraska, Montana, or southern Alberta, winter wheat appears not to be able to survive as low temperatures as in the last-named localities. In fact, considerable spring wheat is grown in Ontario south of the isotherm of 10° F. The lack of any correlation may be because a heavy snow increases the moisture content of the soil in the spring and so increases the danger from heaving. A heavy snow in the spring might therefore overbalance the protection afforded by a snow early in the winter.

Kansas Agricultural Experiment Station,
Manhattan, Kans.

[2] Derr, H. B. Winter barley. U. S. Dept. Agr. Farmers Bul. 518, p. 7. 1912.

[3] Stephens, D. E. Report of the Eastern Oregon Dry-Farming Branch Experiment Station, Moro, Oregon, 1913–14, p. 19. Oreg. Agr. Coll. Expt. Sta., 1914.

[4] Warburton, C. W. Winter oats for the South. U. S. Dept. Agr. Farmers Bul. 436, p. 13. 1911.

# INFLUENCE OF FERTILIZERS AND SOIL AMENDMENTS ON SOIL ACIDITY.[1]

J. J. SKINNER AND J. H. BEATTIE.

## INTRODUCTION.

An experiment with manures, fertilizers, and soil amendments conducted for eight years at the Arlington Farm of the U. S. Department of Agriculture has given an opportunity to study soil acidity, soil oxidation, and other biochemical factors as influenced by fertilizers.

Seven crops were grown, wheat, rye, clover, timothy, corn, cowpeas, and potatoes. Continuous cultivation of the same crop on the same plot year after year was practiced. Each of these crops occupied an area of 1 square rod, making seven crops for each fertilizer treatment. Adjoining each treated plot was an untreated plot growing the same crop. This served as a check or control for the fertilized plot, and in this paper the data of a treated plot are always compared with those of the adjoining untreated plot. The experiment occupied portions of five sections of the farm, the soil varying considerably in the different sections, so no comparisons between widely separated checks should be attempted. In each case the only fair comparison that can be made is between the treated plot and the adjoining untreated plot.

The treated and untreated plots are divided by a 3-foot path, and the portions of the plot growing different crops are divided by 2.5-foot paths. The plots then consist of a strip 1 rod wide, with seven subdivisions each 1 rod square, and parallel to them was a like strip with similar subdivisions, used as a control, growing the same crop.

The soil on which the test was made is a heavy silty clay loam, rather poor physically, and low in organic matter. It is an acid soil which, when limed in sufficient amounts to neutralize the surface 6 inches, within a few months becomes acid again.

The experiment was begun in 1907; clover, timothy, corn, cowpeas, and potatoes were planted in the spring, and wheat and rye in the fall. Each succeeding year each crop was grown on the same plot as in the previous year. The fertilizers and materials added were applied annually before planting.

[1] Contribution from the Office of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Department of Agriculture. Published by permission of the Secretary of Agriculture. Received for publication July 28, 1916.

Samples were taken of the plots in the summer of 1912, when the experiment had been running five years. Five borings were taken with a soil auger from each plot and a composite made. The lime requirements of the soil were determined by the Veitch method.[2] The oxidation power of the soil and other studies were made, but this paper concerns itself with only the acidity or lime requirements of the differently treated plots.

### EFFECT OF SULFATES ON SOIL ACIDITY.

Among the fertilizers used in the experiments were several sulfates, and it is interesting to note the effect of this class of compounds on the reaction of the soil when applied year after year. Those included in the experiment are calcium sulfate, ferrous sulfate, manganese sulfate, copper sulfate, and potassium sulfate. As mentioned, seven plots, each growing a different crop, were fertilized with each of the chemicals and each treated plot lay next to an untreated plot growing the same crop, which is used as a check.

*Calcium Sulfate.*—Calcium sulfate was applied to the plots each year at the rate of 500 pounds per acre. The first application was made in 1907. In the spring of each year the plots growing corn, cowpeas, and potatoes were treated and the fertilizer harrowed in shortly before planting time. The plots growing wheat and rye received their treatment each year in September, before the seeding was done. The clover and timothy plots were treated before seeding when the experiment was started in 1907; thereafter the calcium sulfate was applied to the surface each year in the early spring.

TABLE 1.—*Effect of calcium sulfate on the acidity of the soil producing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 2,130 | 1,710 | 1,430 | 1,780 | 1,700 | 1,780 | 1,420 | 1,707 |
| Soil + calcium sulfate | 2,170 | 2,140 | 2,140 | 2,140 | 1,780 | 2,170 | 1,800 | 2,050 |

Soil samples were taken from each individual plot in June, 1912. Five borings were made in each plot with a soil auger to a depth of

[2] Veitch, F. P. The estimation of soil acidity and the lime requirements of soils. Jour. Amer. Chem. Soc., 24: 1120–1128. 1902.

——. Comparison of methods for the estimation of soil acidity. Jour. Amer. Chem. Soc., 26: 637–662. 1904.

6 inches, and a composite of the five borings made. These samples were used to make the lime requirement tests. The lime requirement for each of the untreated plots and each plot receiving calcium sulfate is given in Table 1. The figures given are the number of pounds of calcium carbonate required to neutralize an acre 6 inches as determined by the Veitch method.

In each plot the soil to which calcium sulfate had been added is more acid than the untreated plot growing the same crop. The lime requirement of all the plots, untreated as well as those treated with calcium sulfate, is high, ranging from 1,400 pounds to 2,100 pounds per acre. The differences in lime requirement of the untreated and calcium sulfate treated plots in some cases is very small, yet in others the differences are very marked. For instance, the untreated wheat plot requires 2,130 pounds of lime and the calcium sulfate plot 2,170 pounds, while with the clover plot the untreated soil requires 1,430 pounds and the calcium sulfate plot 2,140 pounds. However, in each case the calcium sulfate plot has a higher lime requirement than its untreated check. The averages given in the last column show the untreated plots to have a lime requirement of 1,707 pounds and the calcium sulfate plots 2,050 pounds.

*Ferrous Sulfate.*—Ferrous sulfate was used in the experiment at the rate of 50 pounds per acre. The wheat and rye plots received their application in the fall of each year, and the clover, timothy, corn, cowpeas, and potatoes in the spring. The effect of ferrous sulfate on the acidity of the soil treated for five years is quite marked. The fertilization was begun in 1907 and the samples taken for analysis in 1912. The results are given in Table 2.

TABLE 2.—*Effect of ferrous sulfate on the acidity of the soil producing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 2,492 | 2,136 | 1,780 | 2,136 | 2,136 | 2,311 | 1,885 | 2,125 |
| Soil + ferrous sulfate | 2,492 | 2,848 | 2,136 | 2,492 | 2,848 | 3,292 | 3,197 | 2,758 |

An examination of the table shows that in all except one case the lime requirement of the soil is higher in the ferrous sulfate plots than in the untreated plots. Both the untreated and ferrous sulfate plots growing wheat required 2,492 pounds of lime. The differences in the lime requirement of the treated and untreated soil with the

other crops is very marked. The greatest variation occurred in the potato plot; here the untreated soil had a lime requirement of 1,885 pounds and the ferrous sulfate treated plot a lime requirement of 3,197 pounds per acre. The averages given in the last column show an average lime requirement for the seven untreated plots of 2,125 pounds per acre, while the average for the seven ferrous sulfate treated plots is 2,758 pounds per acre.

*Copper Sulfate.*—The details of the experiment with copper sulfate and of the other sulfates to be given are the same as those of the two sulfates already given. Copper sulfate was applied annually at the rate of 50 pounds per acre. The soil when examined was found to be much more acid in the copper sulfate plots than in the untreated plots. The results are given in Table 3.

TABLE 3.—*Effect of copper sulfate on the acidity of the soil producing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 1,770 | 2,136 | 1,885 | 1,780 | 1,426 | 1,534 | 1,742 | 1,753 |
| Soil + copper sulfate | 2,136 | 2,492 | 2,136 | 2,848 | 3,026 | 1,780 | 1,780 | 2,314 |

The difference in acidity of the treated and untreated plots is very marked, except in the plots growing potatoes. In this case the acidity is only slightly more in the copper sulfate plot than in the untreated one. The average lime requirements of the seven plots receiving the chemical was 2,314 pounds per acre against 1,753 pounds as an average for the seven untreated plots.

*Manganese Sulfate.*—The results with manganese sulfate show that it has the same effect on the reaction of the soil as the other sulfate compounds. Manganese sulfate was added annually at the rate of 50 pounds per acre, and after five years of treatment the soil has become more acid than the unfertilized soil. In each case the treated plot is more acid than its check, except with the wheat plots, and here the lime requirements are the same. The average lime requirement of the seven manganese sulfate plots was 2,231 pounds per acre and that of the untreated plots, 1,963 pounds. The results for each plot are given in Table 4.

TABLE 4.—*Effect of manganese sulfate on the acidity of the soil growing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 1,780 | 2,136 | 1,426 | 1,742 | 1,780 | 2,136 | 2,743 | 1,963 |
| Soil + manganese sulfate | 1,780 | 2,492 | 1,780 | 2,136 | 2,492 | 2,492 | 2,451 | 2,231 |

*Potassium Sulfate.*—The results of the experiment with potassium sulfate are given in Table 7 in another connection, but for the sake of continuity will be given here briefly in connection with the action of the other sulfates. The potassium sulfate was applied annually at the rate of 100 pounds per acre and, like the other sulfates, produced a more acid soil than the untreated, which is true with each set of plots. The increase in lime requirement over the check with the wheat plots was 510 pounds per acre; the rye plots, 254 pounds; clover plots, 612 pounds; timothy plots, 1,502 pounds; corn plots, 534 pounds; cowpea plots, 356 pounds; and the potato plots, 303 pounds per acre.

*Potassium Sulfide.*—Potassium sulfide was also used and its effect seems to be similar to that of the sulfate. Potassium sulfide was applied annually at the rate of 200 pounds per acre. The lime requirements of the different plots are given in Table 5.

TABLE 5.—*Effect of potassium sulfide on the acidity of the soil growing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 2,848 | 2,136 | 2,136 | 2,140 | 1,780 | 2,670 | 2,090 | 2,257 |
| Soil + potassium sulfide | 2,918 | 2,492 | 2,492 | 2,140 | 2,140 | 2,490 | 2,140 | 2,402 |

The differences between the treated plot and its check in each case are small, yet in each case except two the lime requirement of the potassium sulfide treated plot is greater than that of the untreated plot growing the same crop. In the wheat plots the untreated soil had a lime requirement greater than the treated plot and in the timothy plots the lime requirement was the same in both. The average lime requirement of seven plots receiving potassium sulfide was 2,402 pounds per acre, while that of the check plots was 2,257 per acre.

The increased acidity of the soil in cases where the sulfates were added was probably due in some cases to the utilization of the base by plants, as potassium and calcium, or by chemical reactions going on in the soil. Some of these compounds, as copper, manganese, and iron sulfate, have a catalytic action in the soil, affecting its oxidation, enzymotic action, and other life activities in such a way as to produce different effects in the soil, depending on its characteristics. With the soil in this experiment the conditions have undoubtedly been such as to promote the activities which tend to produce acidity; in this case the effect of such compounds on the acidity is an indirect one and their influence would be different with different soils. The amount of copper, manganese, and iron sulfate added is not commensurate chemically with the acidity which has developed in the soil with its use.

### EFFECT OF CARBONATES ON SOIL ACIDITY.

*Calcium Carbonate.*—In this soil amendment experiment lime ($CaCO_3$) was used on several plots and in different amounts. One of these sets of seven plots was limed annually at the rate of 300 pounds per acre, and while this soil did not remain neutral under the crop management practiced, its lime requirement at the end of five years was much less than its untreated or check plot. On other plots where lime was applied annually for five years at the rate of one ton per acre, the soil was found to be neutral. The soil under study is naturally an acid one and requires lime annually in considerable quantities to keep it in a neutral condition.

*Magnesium Carbonate.*—In addition to the calcium carbonate interesting results were also secured with magnesium carbonate, which was applied annually at the rate of 200 pounds per acre. At the end of five years the soil was found to be acid but not so much as the untreated plots. In four cases the lime requirement was the same in the magnesium carbonate plot as its check plot, and in three cases the acidity was less where magnesium carbonate was used. The results of the lime requirement determinations are given in Table 6.

TABLE 6.—*Effect of magnesium carbonate on the acidity of the soil growing various crops, as indicated by the pounds of $CaCO_3$ per acre required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated | 1,780 | 2,136 | 1,426 | 2,136 | 1,780 | 2,136 | 2,743 | 2,018 |
| Soil + magnesium carbonate | 1,780 | 2,136 | 1,426 | 1,742 | 1,780 | 1,397 | 1,742 | 1,715 |

The average lime requirement of the seven treated plots was 1,715 pounds per acre, and of the seven check plots 2,018 pounds per acre. In no case was the magnesium carbonate plot more acid than the check.

### EFFECT OF ACID PHOSPHATE, SODIUM NITRATE, AND POTASSIUM SULFATE ON SOIL ACIDITY.

Acid phosphate, sodium nitrate, and potassium sulfate, the commonly used fertilizers, have different effects on the reaction of the soil. It is commonly accepted that soil continually fertilized with sodium nitrate, the nitrate being utilized, eventually becomes alkaline and that this alkalinity causes a sticky physical effect, producing an undesirable soil for crop growth and cultivation. Potassium sulfate, on the other hand, is considered to have the opposite effect, as the potassium is utilized, leaving the acid radical and tending to produce an acid effect in the soil. It has recently been shown by Conner[3] at the Purdue University Agricultural Experiment Station that soils treated with acid phosphate for twenty years show less acidity than soils that have not had phosphate. This, however, probably varies with the nature of the soil, for in this experiment on the Arlington silty clay loam the acid phosphate plots became more acid than the untreated soil but not so acid as the potassium sulfate plot.

TABLE 7.—*Effect of fertilizers on the acidity of the soil growing various crops, as indicated by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated, check A.... | 1,836 | 1,607 | 1,426 | 1,780 | 1,707 | 1,780 | 1,815 | 1,708 |
| Soil + sodium nitrate..... | 1,636 | 1,780 | 1,280 | 1,426 | 1,426 | 1,780 | 1,780 | 1,587 |
| Soil + acid phosphate..... | 2,136 | 1,780 | 1,780 | 1,993 | 1,815 | 2,171 | 2,136 | 1,973 |
| Soil untreated, check B.... | 1,726 | 1,526 | 1,346 | 1,602 | 1,602 | 1,780 | 1,938 | 1,646 |
| Soil + potassium sulfate... | 2,136 | 1,780 | 1,958 | 3,104 | 2,136 | 2,136 | 2,241 | 2,212 |
| Average of Checks A and B | 1,782 | 1,566 | 1,386 | 1,691 | 1,654 | 1,780 | 1,876 | 1,677 |

The plots with these fertilizer treatments lay adjoining; there were seven plots of each fertilizer treatment, each plot growing a different crop. An untreated set of plots lay next to each fertilized plot. The plots were situated so that the results from the differently treated plots growing the same crop were comparable with one another as well as with their check plots. The test was conducted in detail as

[3] Conner, S. D. Acid soils and the effect of acid phosphate and other fertilizers upon them. Jour. Ind. Eng. Chem., 8: 35–41. 1916.

those already given; acid phosphate was applied annually before planting at the rate of 200 pounds per acre, sodium nitrate at the rate of 150 pounds per acre, and potassium sulfate at the rate of 100 pounds per acre. The results of the lime requirement test made after five years of fertilization are given in Table 7.

In the table the lime requirement of the two check plots is given. Check plot A lay first and next to the sodium nitrate plot, and check B is the fourth plot and lay between the acid phosphate and the potassium sulfate plot, serving as a check for both. It is observed that the lime requirement of the two check plots is very close together, check A being in most cases somewhat more acid. The averages of the two checks are given in the bottom line of the table and will be used in comparing the acidity of the fertilized plots.

Considering the sodium nitrate plots, all are shown to be quite acid, but only two show a higher lime requirement than their check. With the rye and potato plots the check plots are less acid, and in the cowpea plots the lime requirement was the same in both treated and untreated soil. In the wheat, clover, timothy, and corn plots the sodium nitrate soil was less acid than the untreated soil. The average lime requirement of the seven sodium nitrate plots was 1,587 pounds per acre, against an average of 1,677 pounds for the checks. Where acid phosphate was used the acidity of the soil was found to be greater than in the unfertilized check. This was true in each of the plots. The average lime requirement of the acid phosphate plots was 1,973 pounds per acre and that of the check plot lying next to it was 1,646 pounds per acre. The potassium sulfate plots were also in every case more acid than the checks. The average lime requirement of the seven potassium sulfate plots was 2,212 pounds per acre against an average of 1,677 pounds for the checks. The potassium sulfate caused a greater acidity than the acid phosphate.

## EFFECT OF STARCH AND MANURE ON SOIL ACIDITY.

Among another class of substances in this experiment were several organic materials, and the acidity of the soil as affected by starch was determined. To the plots concerned potato starch was added annually at the rate of 500 pounds per acre. This was applied before planting and harrowed in, except on the clover and timothy plot, where it was spread on the surface in the spring of each year.

Each of the seven starch plots were more acid than the corresponding check plots after five years of treatment. The differences in the lime requirements in the various plots are small, yet they are consistent throughout the series. The results are given in Table 8.

TABLE 8.—*Effect of starch on the acidity of the soil growing various crops, as determined by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| Soil untreated............ | 2,850 | 2,490 | 2,140 | 2,040 | 2,240 | 2,530 | 2,530 | 2,403 |
| Soil + starch............ | 2,490 | 2,670 | 2,240 | 2,140 | 2,850 | 3,140 | 2,880 | 2,630 |

As seen in the table, the average lime requirement of the seven starch plots was 2,630 pounds per acre, while that for the seven check plots was 2,403 pounds per acre. The decomposition of this organic matter in the soil has produced an acidity greater than is normal for this soil. The influence of organic materials incorporated in soils on its acidity is undoubtedly determined by the process of its decomposition, which is influenced by the nature of the material added, the character of the life processes in the soil, such as bacteria, enzymes, etc., and other soil characteristics. Materials of this nature may produce an altogether different effect in some other soil which has better oxidative power and enzymotic activities.

In this connection the effect of stable manure in producing acidity in the soil is interesting. Well-rotted stable manure was added to the soil in amounts of 4 tons per acre annually. To another plot the manure thoroughly leached was added, and to a third the leachings from the manure were added. The operation was done by spreading cheese cloth over the plots which were to receive the leachings only and spreading the desired amount of manure over the cloth. The boundaries of the plot were banked in such a way that none of the leachings could run away. This operation was done early in the spring, during a rainy spell, and additional water was sprinkled over the manure from time to time so as to assure a thorough and effective leaching. The manure after leaching consisted principally of the straw bedding material and coarse material of the manure. This was then put on the plot which was to receive the leached manure and worked in. Four tons of manure per acre were used for the leaching experiment.

The experiment consisted of five plots, each divided into seven parts and each part growing a different crop. Plot No. 1 was a check and received nothing; No. 2 received the stable manure; No. 3 the leached manure; No. 4 was a check; and No. 5 received the leachings from the manure. These treatments were applied each year before planting, beginning in 1907. The lime requirement was determined in each of the plots in 1912 and is given in Table 9.

TABLE 9.—*Effect of manure on the acidity of the soil growing various crops, as determined by the pounds per acre of $CaCO_3$ required to neutralize the surface 6 inches.*

| Plot No. | Treatment. | Crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Wheat. | Rye. | Clover. | Timothy. | Corn. | Cowpeas. | Potatoes. | Average. |
| 1 | Soil untreated..... | 2,367 | 2,476 | 2,536 | 2,436 | 2,376 | 2,492 | 2,626 | 2,473 |
| 2 | Soil + manure.... | 2,848 | 2,492 | 2,562 | 1,780 | 2,492 | 1,426 | 1,780 | 2,197 |
| 3 | Soil + leached manure......... | 3,282 | 3,560 | 3,104 | 2,492 | 2,492 | 3,104 | 3,560 | 3,085 |
| 4 | Soil untreated..... | 2,490 | 2,613 | 2,753 | 2,692 | 2,431 | 2,543 | 2,451 | 2,567 |
| 5 | Soil + leachings... | 1,958 | 2,136 | 2,136 | 2,136 | 1,426 | 2,241 | 2,136 | 2,024 |
| | Average of checks . | 2,428 | 2,544 | 2,644 | 2,561 | 2,403 | 2,517 | 2,538 | 2,520 |

The table shows that as an average of seven manured plots the lime requirement is less in the manured plot (No. 2) than in the check plots (Nos. 1 and 4). With four of the crops the manured plot was less acid than its check; with the other three crops the manured plots were more acid than the checks growing the same crop. The plot receiving the leached manure (No. 3) was much more acid than its check or the manured plot (No. 2), and the plot receiving the leachings was not as acid as the checks or any of the manured plots.

Considering the averages of the seven plots of each treatment, check No. 1 had a lime requirement of 2,473 pounds per acre; the second check (plot No. 4) had a lime requirement of 2,567 pounds per acre; the manured plots (No. 2) a lime requirement of 2,197 pounds; the leached manured plots, 3,085 pounds; and the plots receiving the leachings from the manure (No. 5), a lime requirement of 2,024 pounds per acre.

The constituents and character of the materials incorporated in the soil in this test have produced different effects. The manure, robbed of its salts and of its soluble nitrogenous and other organic substances, has produced the greatest acidity. The soluble part of the manure, including both the organic and inorganic constituents, has produced conditions which cause a less acid condition than the untreated soil. The degree of acidity of the plots receiving the whole manure (No. 2) is in harmony with the condition of the plots receiving the separate parts of the manure (Nos. 3 and 5), for its lime requirement is less than the plots receiving the leached manure (No. 2) and more than the plots receiving the leachings (No. 5). This substantiates the idea that the straw and insoluble part of the manure by its decomposition in the soil has produced conditions which increase its acidity, and the soluble inorganic and organic portions have

produced the reverse conditions, decreasing the normal acidity of the soil.

SUMMARY.

In an experiment growing wheat, rye, clover, timothy, corn, cowpeas, and potatoes, conducted on a heavy silty clay loam at Arlington, Va., calcium sulfate, ferrous sulfate, manganese sulfate, potassium sulfate, and potassium sulfide added singly to the soil annually for five years increased its acidity.

Magnesium carbonate decreased the acidity of the soil. Soil fertilized with sodium nitrate was less acid than the untreated soil or soil fertilized with acid phosphate or potassium sulfate. Acid phosphate fertilization increased the acidity of the soil, but not as much so as potassium sulfate.

Organic materials affected the soil differently as to causing acidity. Starch caused increased acidity; stable manure slightly increased acidity, which was still greater with manure leached of its soluble organic and inorganic substances. The leachings from manure produced less acidity than the untreated soil and less than the whole manure or leached manure. The nature of the decomposition of the organic material in the soil and the character of the life processes in the soil affects the influence of such substances on soil acidity.

Bureau of Plant Industry,
U. S. Department of Agriculture,
Washington, D. C.

## A METHOD FOR DETERMINING THE PERCENTAGE OF SELF-POLLINATION IN MAIZE.[1]

A. E. Waller,

Ohio State University, Columbus, Ohio.

In genetic studies or in field practice the seed-corn grower often finds that a small culture, if the number of individuals is not increased, soon consists of more or less closely related individuals and a decrease in yield and general vigor of the plant is the normal result. While it is generally recognized that there is some self-pollination in a field of corn, it would be interesting to know just how frequently it occurs naturally. So far as the writer knows, no method

[1] Received for publication June 26, 1916.

has been devised for determining the amount of crossing or selfing that takes place under field conditions. The fact that the number of pollen grains given off from a single plant is estimated in the millions suggests the great opportunity for crossing.

The appearance of dwarfs, plants lacking in chlorophyll, and various other abnormalities supposed to be recessive and carried latent, being hidden by normal (dominant) conditions, can be explained on the Mendelian basis only upon the supposition of a previous self-pollination. This is because there is always a greater chance of bringing out recessive characters when closely related individuals are paired.

In the experiment here described the method used to determine the amount of selfing was quite simple. It consisted of planting hills of white corn in a field of yellow. At the time the corn tasseled two of the three plants in each hill of the white were detasseled. The ears were harvested from the plants upon which the tassels were allowed to remain. Those kernels which had been cross-pollinated were yellow, due to xenia, while those which were self-pollinated were of course white.

In order to insure normal crossing between the white and yellow varieties it was necessary to procure two varieties which mature about the same time. For this purpose a selection of Reid's Yellow Dent developed at the Ohio State University and Wing's Hundred-Day White were used. So far as time of shedding pollen was concerned this was a fortunate combination.

The hills containing the white corn were spaced every eleventh row east and west, a distance of 38½ feet from hill to hill, and every tenth row north and south, a distance of 35 feet from hill to hill. Naturally, climatic conditions would affect the distance apart the hills could be spaced without danger of pollen infection from one white hill to another. When thoroughly dried, the numbers of yellow and of white kernels were counted. The results are shown in Table 1.

Only one pair of endosperm characters was contrasted in this experiment, *i. e.*, white and yellow. Had two contrasting pairs such as color and composition of endosperm been employed the classification of the grains would have been much easier. The yellow was often so weak that it was difficult to distinguish between white and yellow kernels. This was perhaps because in the endosperm formation there was only one set of determiners for yellow, that brought by the second nucleus of the pollen grain, to two sets of determiners for white, those which were contained in the double endosperm

nucleus. In endosperm formation in maize the second nucleus from the pollen fuses with the two polar nuclei in triple fusion; if the male nucleus is the bearer of determiners for a dominant character expressing itself in the endosperm, the phenomenon called xenia then results. In this experiment if, instead of using one recessive endosperm character, white color, a second such as sugary condition of the endosperm had been combined with it, the chance for making a mistake in the classification and counting would largely have been eliminated. However, it would have been difficult to obtain a variety of white sweet corn maturing at the same time the field corn matured, and a series of plantings would have been necessary.

TABLE I.—*Number of yellow (cross-pollinated) and of white (selfed) kernels on ears of white corn, with percentage of selfed kernels.*

| Ear No. | Number of yellow kernels. | Number of white kernels. | Percentage of selfed kernels. | Ear No. | Number of yellow kernels. | Number of white kernels. | Percentage of selfed kernels. |
|---|---|---|---|---|---|---|---|
| 1 | All | 0 | 0 | 20 | 651 | 50 | 7.11 |
| 2 | 379 | 112 | 23.10 | 21 | 691 | 23 | 3.20 |
| 3 | 704 | 5 | 0.70 | 22 | 517 | 3 | 0.58 |
| 4 | 214 | 7 | 3.16 | 23 | 428 | 14 | 3.16 |
| 5 | 564 | 15 | 2.58 | 24 | 372 | 82 | 18.06 |
| 6 | 369 | 13 | 3.40 | 25 | 653 | 28 | 4.11 |
| 7 | All | 0 | 0 | 27 | 671 | 3 | 0.44 |
| 8 | 633 | 29 | 4.38 | 28 | 668 | 15 | 2.19 |
| 9 | 496 | 21 | 4.06 | 29 | 793 | 8 | 1.00 |
| 10 | All | 0 | 0 | 30 | 383 | 0 | 0 |
| 11 | 629 | 0 | 0 | 31 | 806 | 8 | 0.98 |
| 12 | 678 | 26 | 3.69 | 32 | 664 | 55 | 7.64 |
| 13 | 601 | 29 | 4.60 | 33 | 744 | 24 | 3.12 |
| 14 | 496 | 143 | 22.37 | 34 | 773 | 78 | 9.16 |
| 15 | 665 | 21 | 3.06 | 35 | 614 | 31 | 4.80 |
| 16 | 425 | 63 | 12.93 | 36 | 529 | 26 | 4.68 |
| 17 | 695 | 11 | 1.55 | 37 | 616 | 34 | 5.23 |
| 18 | 586 | 89 | 13.18 | 38 | 344 | 54 | 13.50 |
| 19 | 639 | 21 | 3.18 | Average........ | | .......... | 5.13 |

## CONCLUSIONS.

1. The average amount of self-pollination obtained under these conditions was 5.13 percent, but this figure may not represent the percentage of self-pollination taking place under all field conditions, since humidity and wind are factors which determine the zone of infection between hills. To obtain significant figures the experiment should be repeated for several years.

2. Better examples of the effect of xenia can be obtained when more than one contrasting pair of characters are employed.

OHIO STATE UNIVERSITY,
COLUMBUS, OHIO.

# A METHOD FOR DETERMINING THE VOLUME WEIGHT OF SOILS IN FIELD CONDITION.[1]

CHARLES F. SHAW.

In physical and chemical soil studies the determinations of soil moisture, lime, alkali, plant-food ingredients, etc., are most commonly and conveniently reported as percentages by weight, based on water-free soil. When it is desirable to know the total amount of material in the soil studies, it becomes necessary to know the weight of a unit volume of the soil or to know the volume weight. In irrigated farming this knowledge is especially valuable. The wilting point and the total water-holding capacity of the soil can be determined, and from these the avaliable water can be calculated. But as irrigation water is purchased by volume measurements and is expensive, we need to know the volume of water in the soil and the added volume needed to bring the moisture to the desired amount.

There are several methods of determining the volume weight, or apparent specific gravity, of soils. These may be classed under two general heads, those where the measurements are made on disturbed soil and those where the measurements are made on soils in their natural field condition. The first class is best exemplified by the common laboratory method in which the air-dry or oven-dry soil is placed in a brass cylinder or other suitable container, compacted by some arbitrary method, and the weight and volume determined. Of the second class the most common is the so-called King tube method, in which a tube with a suitable cutting edge is forced into the soil for a measured distance and the weight of the enclosed soil used as the basis for determining the volume weight.

The first method has the obvious weakness of dealing with a disturbed soil, and through manipulation of the soil, the results obtained may show a volume weight much greater or much less than that which existed in the original undisturbed or field condition. The second method gives a closer approximation to the true condition but, particularly in heavy soils, the pressure needed to force the tube into the soil causes appreciable compaction of the soil ahead of the tube,

[1] Presented at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1916. Contribution from the Laboratory of Soil Technology, University of California.

modifying the results. In stony or gravelly soils it is almost impossible to use the tubes with any degree of satisfaction.

The method about to be described is not new. It was worked out by the author in 1908 at the Pennsylvania State College, and a brief description was published in 1909 by B. E. Brown and W. F. Cree.[2] A somewhat similar method is mentioned by Stevenson,[3] and one almost identical was worked up by Dr. Rudolf Trnka.[4] This method has been termed the paraffine immersion method. While it is difficult to handle, it offers a means of making very accurate determinations on all but the more sandy soils. In our experiments blocks of soil about 1 foot square and 6 inches deep were carefully cut from the soil mass and lifted on broad-bladed spatulas to a table, where the block was divided into smaller blocks, from 4 to 6 inches square and 6 inches deep. In subdividing the block great care was taken to preserve the full 6-inch depth and the general cross section, but the exact shape or size of the cross section was not so important. From the base soil secured in preparing these blocks, small samples were taken for moisture determinations, in order to correct the weight to the water-free basis.

The blocks were placed on a weighed support or dipping device and carefully weighed, then dipped several times in melted paraffine. The coating of paraffine should be heavy enough to stand some necessary handling and should be waterproof. After cooling, the blocks were weighed to determine the amount of paraffine taken up. The paraffined soil was then weighed in water, the difference in weight showing the weight of the water displaced. In some of our work, instead of weighing in water, the volume was determined by actual measurement of water displacement, either by placing the block in a container of known capacity and measuring the amount of water needed to fill, or by immersing in a vessel full of water and measuring the water that flowed from the outlet.

After the weighing or measuring was completed the block was broken up to recover the paraffine and to note any unusual features, such as worm holes, excessive quantities of roots or stones, or any other feature that would make the sample exceptional. In some

[2] Brown, B. E., MacIntire, W. H., and Cree, W. F. Comparative physical and chemical studies of five plats, treated differently for twenty-eight years. *In* Ann. Rpt. Pa. Agr. Expt. Sta. 1909–10, pp. 96, 97. 1910.

[3] Stevenson, W. H. A new soil sampler. Iowa Agr. Exp. Sta. Bul. 94, 31 p., 9 fig. 1908.

[4] Trnka, Rudolf. Eine Studie über einige physikalischen Eigenschaften des Bodens. Internat. Mitt. für Bodenkunde, bd. 4, heft 4/5, p. 363–387. 1914.

cases, where an unusual number of pebbles was present, they were collected, washed, dried, and weighed. Their volume was then determined by immersing in a graduated cylinder and suitable deductions made from the soil figures.

From the data thus obtained the volume weight was calculated by the following formula:

$$\frac{M(100 - P) - R}{V - \frac{(N - M)}{.9} - R'} = S = \text{Volume weight, where}$$

$M$ = weight of soil in field condition;
$N$ = weight of soil and paraffine;
$V$ = volume of soil and paraffine;
$P$ = percentage of water in the soil;
$R$ = weight of stone in the soil;
$R'$ = volume of stone in the soil; and
.9 = specific gravity of the paraffine.

The volume and weight of the dipping device being constant, they are not included in $M$, $N$, and $V$.

The results shown in Table 1 were obtained at the Pennsylvania State College in 1908 and 1909 by using this method.

TABLE 1.—*Weight per cubic foot of soil as determined by the paraffine immersion method.*

| Plot No. | Treatment. | No. of trials. | Volume weight. | Weight per cubic foot, lbs. |
|---|---|---|---|---|
| 1 | Check | 6 | 1.3366 | 83.479 |
| 2 | Dried blood | 3 | 1.3410 | 82.910 |
| 3 | Dissolved bone black | 2 | 1.2850 | 80.250 |
| 4 | Muriate of potash | 3 | 1.2500 | 78.160 |
| 5 | $N-P$ | 4 | 1.2000 | 75.005 |
| 6 | $N-K$ | 4 | 1.3100 | 82.100 |
| 9 | $N-P-K$ | 8 | 1.3675 | 85.310 |
| 15 | $P-K$ | 3 | 1.4100 | 88.180 |
| Average | | 33 | 1.3128 | 81.923 |

In making calculations for fertilizer treatments on these plots, the experiment station had been using 70 pounds as the weight per cubic foot of this soil.

In the summer of 1916, in cooperation with Mr. O. W. Israelson, of the Division of Irrigation Investigations of the California station, measurements were made on the Willows clay, a compact silty clay having a dense structure. Water percolates into this soil very slowly, making irrigation very difficult. In this work extreme care was taken to get accurate results, although we were somewhat handi-

capped by the necessity of doing the work in the field, over 100 miles from the laboratory. The samples were taken at about 6-inch depths, though the necessity of leveling off the column before taking the next sample reduced the depths somewhat. Samples were taken to a depth of 5 feet, being cut from the side of a large hole which was dug to facilitate getting at the soil. The results are shown in Table 2.

TABLE 2.—*Volume weight of Willows clay at various depths, as determined by the laboratory and the paraffine immersion methods.*

| Depth of soil, inches. | Volume weight. | |
|---|---|---|
| | Laboratory method (average of 12 determinations). | Paraffine immersion method (average of 3 determinations). |
| 2– 7 | 1.380 ±.007 | 1.671 ±.004 |
| 8–13 | | 1.702 ±.008 |
| 15–20 | | 1.784 ±.007 |
| 22–27 | | 1.802 ±.002 |
| 28–33 | | 1.802 ±.007 |
| 35–40 | 1.320 ±.004 | 1.792 ±.000 |
| 42–47 | | 1.757 ±.012 |
| 48–53 | | 1.741 ±.010 |
| 54–60 | | 1.541 ±.028 |
| Average......... | 1.350 ±.008 | 1.733 ±.035 |

It will be noted that the results in this case agree with those from Pennsylvania in indicating that the soil in its natural field condition is much heavier than is indicated by the laboratory method. In the article already mentioned, Trnka also cites results showing the natural soil condition to be consistently more dense than the laboratory methods show. There seems to be sufficient evidence that the older methods gave results that were quite different from those existing in the field, emphasizing the necessity for more careful study by more accurate methods.

During 1915 and 1916 Mr. O. W. Israelson and others in the Division of Irrigation Investigations at the California station, working in cooperation with the Farm Irrigation Investigations of the U. S. Office of Public Roads and Rural Engineering, developed a new method for rapid approximate determinations of volume weight of soils in the field condition. This will be more fully discussed in a later publication, and will be but briefly mentioned here.

The apparatus consists of a straight-sided soil auger of the post-hole type—a cylinder with two side cutting edges,—a long tube of thin rubber of slightly smaller diameter than the auger, a large graduated cylinder, and a hand pump. A hole is bored to the desired depth,

all the soil being carefully collected, sampled for moisture, and weighed. The rubber tube is carefully inserted in the hole, and water is measured in until the tube is filled to the top of the hole. The water is then pumped out, and the tube removed and dried. The process is repeated until the final desired depth is reached. This method, when checked against the paraffine immersion method, gave very close results. On the Willows soil the rubber tube method showed a volume weight of $1.744 \pm .010$ while the paraffine immersion method gave $1.733 \pm .035$. Checked against the laboratory method the rubber tube method gave the results shown in Table 3.

TABLE 3.—*Volume weights of various soils as determined by the laboratory and the rubber tube methods.*

| Soil. | Volume weight. | |
|---|---|---|
| | Laboratory method. | Rubber tube method. |
| Fine sandy loam | 1.20 | 1.280 |
| Loam | 1.22 | 1.210 |
| Clay | 1.13 | 1.257 |
| Clay loam | 1.18 | 1.398 |
| Clay | 1.34 | 1.642 |
| Silty clay | 1.38 | 1.741 |
| do. | 1.35 | 1.750 |
| Fine sandy loam | 1.28 | 1.112 |
| Loam | 1.20 | 1.289 |
| Clay loam | 1.35 | 1.272 |

These figures show that there usually is a marked difference between the results obtained by the two methods, and further emphasize the importance of a more careful study of the problem.

LABORATORY OF SOIL TECHNOLOGY,
UNIVERSITY OF CALIFORNIA,
BERKELEY, CAL.

# AGRONOMIC AFFAIRS.

## THE SOCIETY IN 1917.

The American Society of Agronomy is now entering on its tenth year. Organized on December 31, 1907, it has grown to a society of more than 600 members in nine years. Its membership has increased most rapidly during recent years, largely because the issuance of a journal has greatly increased its interest to agronomic workers. With the greater frequency of issue incident to the current volume, this interest should be heightened and the membership still largely increased. The Society should have every agronomic worker in the United States and Canada on its roll, with many representatives in other countries as well. By the end of its tenth year it should have at least 750 members. If only one in four of the present members brings in a new member during the year the 750 mark will be more than passed. The Secretary is doing what he can to bring the Society to the attention of nonmembers, by means of circular letters and sample copies of the JOURNAL, but a personal invitation is a far more effective means of inducing men to join.

With the increasing membership, each member receives more from the Society. In 1916, 25 percent more pages of agronomic matter were printed in the JOURNAL than in the previous volume. There will be a further increase in 1917. Of more importance, however, is the greater frequency of publication. At a meeting of the Executive Committee in November, the publication of nine numbers in 1917 was authorized, these to appear monthly from January to May and from September to December. It is the plan to have the JOURNAL appear about the fifteenth of each month. This more frequent and regular publication should add to its value and usefulness. Papers on agronomic subjects are solicited, especially those from 2 to 8 pages in length. Longer papers are frequently accepted and are always useful, but it is the aim of the Editor to have matter in the JOURNAL presented in crisp, concise form. A short paper will often be read in its entirety, while a longer one will be read by title only and then put aside for reading at a more convenient time, with the result that it is not read at all.

The annual meeting of the Society in Washington in November was a markedly constructive one. The committees of the Society

are doing excellent work and are formulating plans of much value. Agronomic workers everywhere should know of this work and should help in it. This knowledge and cooperation can be gained only by membership in the Society. The series of papers on agronomic terminology contributed by the committee on that subject will be continued from time to time during the year, and other series of interest and value are projected for the JOURNAL. If we work together, we can make 1917 by far the best year that the American Society of Agronomy has ever known. Will you not ask at least one man to join the Society today?

## ANNUAL DUES OF MEMBERS.

Two changes were made in the by-laws of the Society at the November, 1916, meeting, both of which affect the payment of annual dues. These are recorded in the minutes of the meeting published in the November–December JOURNAL, but for convenience are reproduced here, the changes being printed in italics:

1. The annual dues for each active and associate member shall be $2.00, and for each local member 50 cents, *which shall be due and payable on January 1* of the year for which membership is held.

2. *The Journal of the American Society of Agronomy shall not be sent to any member whose dues are not paid by April 1 of the year for which membership is held.*

According to these by-laws, dues are now payable on January 1 instead of April 1, and membership in the Society lapses unless dues are paid within the calendar year for which membership is held. In the past, lapsed members received the JOURNAL through an entire year and until April 1 of the year following, for which the Society received no payment. Now, the delivery of the JOURNAL is stopped on April 1 of the year for which membership is held, if dues are not paid by that time. This seems to be an eminently fair arrangement, as those who are not sufficiently interested in the Society to pay its annual dues certainly have little interest in the JOURNAL, while the expense of sending the magazine to them is not a justifiable charge against those who pay the membership fee regularly. Members are urged, therefore, to remit their dues for 1917 promptly to the Treasurer, Prof. George Roberts, Experiment Station, Lexington, Ky. Prompt remittance will not only lessen the work of that faithful officer but will insure prompt and regular delivery of the JOURNAL through 1917.

## MEMBERSHIP CHANGES.

The membership of the Society at the end of 1916 was 586. Since that time 24 new members have been added, 1 has been reinstated, and 2 have resigned, making a net gain of 23. The membership of the Society, therefore, is now 609. The names and addresses of these men, with such changes of address as have been reported to the Secretary, follow. The address of one member, Robert K. Bonnett, which was incorrectly given in the address list published in the preceding number of the JOURNAL, is also printed here.

### NEW MEMBERS.

ALBERT, A. R., Dept. of Soils, College of Agriculture, Madison, Wis.
BREWER, HERBERT C., The Barrett Company, 17 Battery Place, New York, N. Y.
BRIGGS, GLEN, 318 West St., Stillwater, Okla.
BROCKSON, W. L., Agr. Expt. Sta., University of Illinois, Urbana, Ill.
CURTIS, HARRY P., 1103 West Springfield Ave., Urbana, Ill.
DOUGLAS, J. P., 402 East Chalmers St., Urbana, Ill.
GRAY, SAMUEL D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
HANSON, LEWIS P., Dept. of Soils, College of Agriculture, Madison, Wis.
HARLAN, HARRY V., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
HASKELL, E. S., Farm Management, U. S. Dept. Agr., Washington, D. C.
HODGSON, E. R., Agr. Expt. Sta., Blacksburg, Va.
HULBERT, HAROLD W., Farm Crops Dept., Iowa State College, Ames, Iowa.
HUSTON, H. A., German Kali Works, 42 Broadway, New York, N. Y.
JOSLYN, H. L., Craven Co. Farm Life School, Vanceboro, N. C.
KELLY, E. O. G., Wellington, Kans.
KEMP, ARNOLD R., 402 Chalmers St., Champaign, Ill.
LONGMAN, O. S., Olds Agricultural School, Olds, Alberta, Canada.
MORISON, A. T., Dept. Agronomy, Agr. Expt. Sta., Urbana, Ill.
MOYNAN, JOHN C., Cereal Husb. Dept., Macdonald College, Quebec, Canada.
NORTHROP, ROBERT S., Box 442, Redding, Cal.
OSENBRUG, ALBERT, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
PARK, J. B., Farm Crops Dept., Ohio State University, Columbus, Ohio.
PURINGTON, JAMES A., Mass. Agricultural College, Amherst, Mass.
WILLARD, C. J., 919 Nevada St., Urbana, Ill.

### MEMBER REINSTATED.

MARBUT, C. F., Bur. Soils, U. S. Dept. Agr., Washington, D. C.

### MEMBERS RESIGNED.

CARNES, HOMER M., North Powder, Oreg.
SWEET, CARL, Dominion Seed Branch, Regina, Sask., Canada.

### CHANGES OF ADDRESS.

ATWATER, C. G., Agr. Dept. The Barrett Co., 17 Battery Place, New York, N. Y.
BONNETT, ROBERT K., Kans. State Agr. College, Manhattan, Kans.
WOODARD, JOHN, 381 Paisley Road, Guelph, Ont., Canada.

## NOTES AND NEWS.

W. A. Albrecht has been elected instructor in soils at the University of Missouri.

William W. Baer has been appointed assistant chemist at the New York state station for work in the agronomy department.

E. C. Bowers has been elected instructor in agronomy at the Virginia Polytechnic Institute.

N. I. Butt is now assistant in agronomy at the Utah college and station.

H. J. Conlin has been appointed assistant in soils at the Ohio station.

W. B. Ellett, chemist of the Virginia station, has been appointed professor of agricultural chemistry in the Virginia college in addition to his station work.

R. A. Kinnaird, who for the past year has been teaching agriculture at the normal school at Maryville, Mo., is now extension instructor in soils in the University of Missouri.

J. D. Luckett, formerly of the Purdue University station, is now on the editorial staff of the Experiment Station Record, where he is giving special attention to publications on field crops.

A. M. Peter, for the past several years chemist of the Kentucky station, has recently been elected director of that station.

M. N. Pope, instructor in biology and agriculture in the St. Paul central high school last year, is now teaching the same subjects in the State Normal School at Eau Claire, Wis.

Phil E. Richards, assistant in agronomy and graduate student at Ohio State University during the past year, is assistant in soil research at the Maryland station.

Newell S. Robb, formerly assistant agronomist in the University of Idaho, since June 15 has been county agent in Lane County, Oregon, with headquarters at Eugene.

Nickolas Schmitz, agronomist of the Maryland station, has been elected agronomist in the extension division at the Pennsylvania State College. He will have charge of all extension work in agronomy in Pennsylvania.

Clinton D. Smith, former director of the Arkansas, Minnesota, and Michigan stations and for five years president of the Louis Queiros school of agriculture at Sao Paulo, Brazil, died at Buffalo, N. Y., August 5, at the age of 62 years.

W. H. Smith, state superintendent of education, has been appointed president of the Mississippi Agricultural College, succeeding George R. Hightower on September 15.

George Stewart, assistant in soils at the Utah college and station, is pursuing graduate study at Cornell University.

F. W. Stemple, formerly instructor in agronomy at Ohio State University, is now professor of agronomy and agronomist of the West Virginia college and station.

R. W. Thatcher has recently been appointed assistant director of the Minnesota station, in addition to his other duties. Dr. Thatcher is also acting president of the newly organized American Association for the Promotion of Technical Training in India, a society which is planned to be of assistance to Hindoo students in the United States and to aid them in developing industrial education on their return to India.

John B. Wentz, who has been engaged in post-graduate work at Cornell University during the past year, is now associate professor of farm crops at the Maryland State College.

Leroy D. Willey, formerly assistant in dry-land agriculture on the Cheyenne Experiment Farm, Archer, Wyo., is now superintendent of the newly established Sheridan Field Station at Sheridan, Wyo.

*The Agricultural Digest,* the first issue of which appeared early in the summer, is the official publication of the National Agricultural Society. The *Digest* will contain reviews of the leading articles in the various farm papers and of federal and state bulletins on agriculture, and also original articles on timely topics. The National Agricultural Society, "a national organization for the promotion of agriculture," was organized on April 27, 1916. Hon. James Wilson, former Secretary of Agriculture, is president; G. Howard Davidson, chairman of the executive committee; P. C. Long, secretary; and Walter A. Johnson, treasurer. The headquarters of the Society are at 2 West 45th Street, New York. If financial strength is a prime requisite, the society should be an immediate success, for its board of directors contains such names as those of Theodore N. Vail, T. Coleman du Pont, William H. Moore, and Samuel Insull. While the

interest of these men in agriculture is unquestioned, their fame is due much more largely to their commercial successes.

*Appropriations for the U. S. Department of Agriculture.*

The appropriations act for the Federal Department of Agriculture for the fiscal year ending June 30, 1917, which was approved by the President on August 11, set aside nearly $25,000,000 for the year's work. This is an increase of almost $2,000,000 over the appropriation for the previous year. The new legislation carried by the bill includes the U. S. grain standards act and the U. S. warehouse act.

The increases in appropriations for the more important bureaus and offices were divided as follows: Weather Bureau, $81,000, principally for increased weather and storm-warning service in Panama and Alaska; Bureau of Animal Industry, $435,000, a large part of which is for control of contagious diseases of animals and the eradication of the Texas fever tick; Bureau of Plant Industry, $398,-which is for control of contagious diseases of animals and the balance is distributed over numerous projects; Forest Service, $996,-000, for the purchase of eastern lands for forest purposes and for road construction in national forests; Bureau of Soils, $175,000, for investigating methods of obtaining potash on a commercial scale; Bureau of Biological Survey, $132,000, for the destruction of predatory animals; States Relations Service, $148,000, principally for demonstration work; and Office of Markets and Rural Organization, $388,000, principally for the establishment of a market news service on live stock, meats, fruits, and vegetables. The principal decrease in the bill is the cutting in half of the $2,500,000 emergency appropriation available last year for the eradication of the foot and mouth disease. This emergency appropriation is available only as necessary to combat outbreaks of foot and mouth or other contagious animal diseases.

Other acts of the Congress which adjourned on September 9 include the following increases in appropriations for agricultural purposes over those of the previous year: Smith-Lever extension fund, $500,000; printing fund, $100,000; cooperative construction of rural post roads, $5,000,000; and cooperative construction of roads and trails in the nationals forests, $1,000,000.

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# THE SOIL MULCH.[1]

L. E. Call and M. C. Sewell.

## Introduction.

It is a matter of common belief and teaching that the soil is cultivated principally to maintain an earth mulch in order to prevent evaporation and to conserve moisture. The purpose of this paper is to review the experiments in soil mulches which have been conducted and to present certain results which do not conform to accepted teachings.

It has usually been taught (1) that the soil moisture is capable of movement through capillary force; (2) that this force is a result of the forces of cohesion and surface tension, when the latter is not in a state of equilibrium;[2] (3) that the phenomena of surface tension are due to the existence of molecular forces; and (4) that moisture within the soil exists in the form of films about the soil particles.

The phenomena are illustrated by the suspended drop of water. The particles in the interior of the drop are attracted equally in all directions by the other particles of the liquid. This is cohesion or the attraction of like molecules of matter. A molecule on the surface of the drop is not attracted equally on all sides, since the molecules of gas surrounding the drop have less attraction for the particles than is exerted by the particles within the liquid. Hence the resultant attraction is inward, and there is formed a membrane, as it were, of

[1] Contribution from the Kansas Agricultural Experiment Station. Presented by the junior author at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1916.

[2] Briggs, Lyman J. The mechanics of soil moisture. U. S. Dept. Agr., Bur. Soils Bul. 10. 1897.

uniform tension. Thus we have the soil moisture, except in cases of saturated soil, in the form of films. These films of water about respective soil particles grouped together exert a pressure dependent upon the capillary angle, which is the angle formed between the liquid-solid and the liquid-gas surface. The angle is dependent upon the form of the film. Considering three particles of soil enclosed with films in contact, and one of these films connecting the water held in two adjacent capillary spaces containing different quantities of water, the capillary angle between the film with the less water and the joining film will have the greater curvature and pressure outward. Hence the angle being greater and outward pressure being greater, water will be drawn over until equilibrium exists between the pressure exerted by the water in the two capillary spaces. Such movement exists between all of the soil particles, the tendency being to bring about a condition of equilibrium between the pressures of adjacent films. If the surface tension of water in the upper layers of soil is increased, water is drawn toward that point. This in brief constitutes the theory of the movement of soil moisture.

### The Theory of Soil Mulches.

The theory of the soil mulch in preventing or checking evaporation of soil moisture is that by loosening the surface by cultivation the soil particles are removed from intimate contact with one another, the films lose most of their water by evaporation, and the movement of water to the surface is thus prevented. In other words, the dry layer of soil acts as a blanket in checking evaporation.

### Review of Literature.

Laboratory experiments in which columns of soil in glass or brass containers are kept in contact with free water,[3] and tank or lysimeter experiments in which a block or column of soil is kept in contact with a water table have fully demonstrated capillary movement of moisture for such conditions.[4] But capillary movement without the presence

[3] King, F. H. Textbook of the physics of agriculture, p. 161–170, 186. 1910.
Hilgard, E. W. Soils; their formation, properties, compositions, and relations to climate and plant growth in the humid and arid regions, 1st ed., p. 203. The Macmillan Co., New York. 1902.

[4] Fortier, Samuel. Soil mulches for checking evaporation. *In* U. S. Dept. Agr. Yearbook 1908, p. 465–472. 1909.
King, F. H. Investigations relating to soil moisture. *In* Wis. Agr. Expt. Sta. 8th Ann. Rpt., p. 100–134. (1891) 1892.
—— Investigations of soil management. U. S. Dept. Agr., Bur. Soils Bul. 26, p. 198–205. 1905.
Willard, R. E., and Humbert, E. P. Soil moisture. New Mex. Agr. Expt. Sta. Bul. 86. 1913.

of a water table (with a dry subsoil) has not been demonstrated. In the Great Plains region the latter condition is the more common, since on the uplands a water table is seldom encountered at depths of less than 60 feet. Because of the winds and dry atmosphere, the rate of evaporation also is higher than in more humid climates. Since the rate of evaporation may be more rapid than the rate of capillary movement to the surface, a natural air-dry mulch may be formed without cultivation. Hence, in such conditions, cultivation to conserve moisture might be of little value.

Burr[5] found at the North Platte (Nebr.) station that no water was drawn from the fifth foot to replace that which had been used by alfalfa on bench land underlaid with sheet water from 17 to 21 feet below the surface. In a period of seventeen months the moisture content of the fourth and fifth feet remained about constant. Burr concluded that "the plant roots to obtain water, extend themselves into the soil zone where available water is present, rather than depend upon the water being brought to them by capillarity."

This conclusion is supported by the work of Miller[6] in his study of the root systems of corn, kafir, and milo at the Garden City (Kans.) Branch Experiment Station during the seasons of 1914 and 1915. It was found that the root systems of the crops by the latter part of August had extended themselves throughout the sixth foot of soil. From moisture determinations which were made a few days before or after the isolation of the various root systems, it was concluded that "the results of these experiments for both seasons seem to show that there was little if any depletion of the soil moisture below the depth to which the roots penetrated."

Alway[7] studied the growth of plants and their use of moisture when grown in water-tight cylinders at the Nebraska station. He found that the moisture becomes available to the plants by the development of roots to moist soil, and that but little moisture is elevated to the roots by capillarity.

The capillary movement of moisture was studied at the New Mexico station[8] by lysimeter experiments. The maximum rise of moisture from water through sandy loam was found to be 32 inches and

[5] Burr, W. W. The storage and use of soil moisture. Nebr. Agr. Expt. Sta. Research Bul. 5. 1914.

[6] Miller, Edwin C. Comparative study of the root systems and leaf areas of corn and the sorghums. *In* U. S. Dept. Agr., Jour. Agr. Research., v. 6, no. 9, p. 311–331. 1916.

[7] Alway, F. J. Studies on the relation of the nonavailable water of the soil to the hygroscopic coefficient. Nebr. Agr. Expt. Sta. Research Bul. 3. 1913.

[8] Willard, R. E., and Humbert, E. P. Loc. cit.

through adobe clay 50.5 inches. The movement of moisture from wet to dry soil was very slight, although moisture rose 30 inches from wet soil to the roots of a crop of wheat.

Barker,[9] of the Nebraska station, reported that the loss of water because of direct evaporation from the surface of the soil is very small after the water becomes thoroughly distributed. Young,[10] of the same station, found that the soil mulch is not more effective than an unmulched soil in retarding the evaporation of the moisture that is well established in the soil; that if a hard layer of soil dries out to the depth of 2 or 3 inches it will act as a mulch; and that the loss of water from the soil is largely due to transpiration from plants. This last conclusion is supported by Alway,[11] who found in studies conducted at the Nebraska station that the loss of water from the subsoil of dry lands under crop seems to take place almost entirely through transpiration. In the absence of plants, the loss from the subsoil is small.

A review of tillage experiments[12] shows that no field experiments

[9] Barker, P. B. The moisture content of field soils under different treatments. *In* Nebr. Agr. Expt. Sta. 25th Ann. Rpt., p. 106–110. (1911) 1912.

[10] Young, H. J. Soil mulch. *In* Nebr. Agr. Expt. Sta. 25th Ann. Rpt., p. 124–128. (1911) 1912.

[11] Alway, F. J. Loc. cit.

[12] Atkinson, Alfred, Buckman, H. O., and Gieseker, L. F. Dry farm moisture studies. Mont. Agr. Expt. Sta. Bul. 87. 1911.

Barker, P. B. Loc. cit.

Buckman, H. O. Moisture and nitrate relations in dry-land agriculture. Proc. Amer. Soc. Agron., 2: 131. 1910.

Cardon, P. V. Tillage and rotation experiments at Nephi, Utah. U. S. Dept. Agr. Bul. 157. 1915.

Jardine, W. M. Arid farming investigations. Utah Agr. Expt. Sta. Bul. 100. 1906.

Linfield, F. B., and Atkinson, Alfred. Dry farming in Montana. Mont. Agr. Expt. Sta. Bul. 63. 1907.

Lipman, C. B. Plowing and cultivating soils in California. Cal. Agr. Expt. Sta. Circ. 98. 1913.

Loughridge, R. H. Moisture in California soils during the dry season of 1898. *In* Cal. Agr. Expt. Sta. Ann. Rpt. 1897–8, p. 65–96. 1900.

Schollander, E. G. Moisture conservation. *In* Williston (N. Dak.) Subexpt. Sta. 3d Ann. Rpt., p. 61–63. 1910.

Shutt, Frank T. The moisture content of packed and unpacked soils. *In* Rpt. of the Chemist, Expt. Farms Rpts. (Canada), p. 172. 1911.

Widtsoe, John A. The storage of winter precipitation in soils. Utah Agr. Expt. Sta. Bul. 104. 1908.

—— Irrigation investigations: factors influencing evaporation and transpiration. Utah Agr. Expt. Sta. Bul. 105. 1909.

Young, H. J. Loc. cit.

on the same soil types have been conducted in which the moisture content of cultivated surfaces and surfaces bare of all vegetation but uncultivated have been compared, except the experiment of H. J. Young at the Nebraska station. Experiments conducted at the Kansas station at Manhattan and at the Garden City substation were planned to show this comparison. The writers believe that the data secured are of value in the consideration of economic tillage.

## Experimental Data on Soil Moisture.

Experiments in which uncropped areas were (1) cultivated and (2) left uncultivated but kept free of weeds were begun at Manhattan in 1909 and at Garden City in 1912. In both cases moisture determinations were made to a depth of several feet. The experiments at Manhattan were discontinued at the close of the 1909 season but were resumed again in 1914.

### EXPERIMENTS AT MANHATTAN.

Soil samples were taken to a depth of 6 feet at Manhattan in 1909. The moisture determinations expressed in percentages and in inches of water are presented in Table 1. The soil was a Marshall silt loam and the plots one twentieth acre in size. The uncultivated plot was kept bare of vegetation by scraping with a hoe and the cultivated plot was worked with a 1-horse cultivator.

Table 1.—*Moisture content (calculated to dry soil) of soil at various depths from cultivated and uncultivated plots at Manhattan, Kans., in May, July, and August, 1909.*

| Depth (feet). | May. | | | | July. | | | | August. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cultivated. | | Uncultivated. | | Cultivated. | | Uncultivated. | | Cultivated. | | Uncultivated. | |
| | Per-cent. | Inches. | Per-cent. | Inches. | Per-cent. | Inches. | Per-cent. | Inches. | Per-cent. | Inches. | Per-cent. | Inches |
| 1 | 28.42 | 4.26 | 27.89 | 4.18 | 26.07 | 3.91 | 24.33 | 3.65 | 23.06 | 3.46 | 20.55 | 3.08 |
| 2 | 25.42 | 4.14 | 25.51 | 4.16 | 25.07 | 4.09 | 26.66 | 4.34 | 24.52 | 3.99 | 25.64 | 4.18 |
| 3 | 21.54 | 3.86 | 21.87 | 3.92 | 21.40 | 3.83 | 22.25 | 3.90 | 21.04 | 3.77 | 20.61 | 3.69 |
| 4 | 20.25 | 3.81 | 20.48 | 3.86 | 21.28 | 4.01 | 20.21 | 3.80 | 20.41 | 3.84 | 20.05 | 3.77 |
| 5 | 20.02 | 3.51 | 20.82 | 3.66 | 20.53 | 3.61 | 29.60 | 5.20 | 20.29 | 3.57 | 19.54 | 3.43 |
| 6 | 20.73 | 3.48 | 21.00 | 3.52 | 20.89 | 3.67 | 20.29 | 3.40 | 20.16 | 3.38 | 19.31 | 3.24 |
| Total...... | ..... | 23.06 | ..... | 23.30 | ..... | 23.12 | ..... | 24.29 | ..... | 22.01 | ..... | 21.39 |

During the season the mulched plots lost a total of 1.05 inches of water and the unmulched, 1.91 inches, the difference probably being within the experimental error.

The experiment was resumed in a modified form in the spring of

1914. Four plots were included, (1) cultivated 3 inches deep; (2) cultivated 6 inches deep; (3) not cultivated, weeds allowed to grow; and (4) not cultivated, but weeds removed by scraping. The available plant food as indicated by nitrate determinations in mulched and nonmulched plots was also determined.

The size of the plots was 12 feet by 25 feet. The soil is known as a Marshall silt loam. The moisture equivalent of this soil is 27.52

TABLE 2.—*Moisture content (percentage of dry weight of soil) of mulched and unmulched plots at Manhattan, Kans., on various dates in 1914.*

| Date of sampling. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| April 13 | 22.36 | 23.01 | 19.34 | 21.54 |
| May 19 | 18.30 | 19.52 | 17.93 | 16.47 |
| June 4 | 16.85 | 17.83 | 14.98 | 19.38 |
| July 9 | 14.42 | 22.37 | 22.78 | 22.08 |
| July 23 | 15.38 | 18.22 | 18.33 | 19.62 |
| August 5 | 13.88 | 18.67 | 17.45 | 17.00 |
| August 25 | 13.12 | 16.87 | 16.37 | 15.13 |
| November 2 | 15.08 | 19.70 | 17.48 | 20.65 |
| Average | 16.16 | 19.52 | 18.08 | 18.98 |
| Loss, Apr. 13 to Nov. 2 | 7.28 | 3.31 | 1.86 | 0.89 |

percent and the wilting coefficient by the formula of Briggs and Shantz is 14.96 percent. Soil samples were taken to a depth of 6 feet for moisture and 3 feet for nitrate determinations. The data obtained in 1914 are summarized in Table 2.

The bare-surface treatment sustained the least loss of soil moisture during the whole of this season. The 6-inch mulch was superior to the 3-inch mulch in checking loss by evaporation. The plots were

TABLE 3.—*Moisture content (percentage of dry weight of soil) of mulched and unmulched plots at Manhattan, Kans., on various dates in 1915.*

| Date of sampling. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| April 15 | 22.90 | 23.00 | 22.95 | 23.00 |
| May 8 | 23.50 | 23.30 | 23.14 | 22.70 |
| June 16 | 23.90 | 24.10 | 23.94 | 22.90 |
| July 5 | 22.30 | 23.80 | 23.06 | 22.80 |
| July 27 | 21.60 | 22.10 | 21.81 | 21.30 |
| August 24 | 21.80 | 23.80 | 23.00 | 22.00 |
| September 8 | 21.70 | 23.70 | 22.90 | 22.30 |
| Average | 22.50 | 23.40 | 22.90 | 22.40 |
| Gain or loss, Apr. 15 to Sept. 8 | −1.20 | 0.70 | −0.05 | −0.70 |

continued in 1915 as in the previous season. The data are summarized in Table 3.

The precipitation for 1915 was very heavy, the total from January to September, inclusive, being 44.97 inches, as compared with 17.93 inches and 29.89 inches for the same periods during 1914 and 1916. It is probable that the slightly higher moisture content of the mulched plots at the end of the season as compared with the bare surface plot is due to the heavy rainfall and the better condition of the surface to absorb water.

The plots used in 1914 and 1915 for the mulch studies were seeded to fall wheat in October, 1915. In the spring of 1916 a new series of plots was established on the same soil type and handled in the same way. The results obtained are presented in Table 4.

TABLE 4.—*Moisture content (percentage of dry weight of soil) of plots variously treated at Manhattan, Kans., in 1916.*

| Date of sampling. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| May 29 | 21.05 | 21.16 | 18.88 | 20.25 |
| July 1 | 14.55 | 15.52 | 13.22 | 15.99 |
| July 29 | 15.63 | 19.91 | 15.79 | 19.07 |
| August 26 | 14.08 | 20.11 | 16.91 | 17.63 |
| September 23 | 14.40 | 18.77 | 17.69 | 17.75 |
| Average | 15.94 | 19.09 | 16.49 | 18.14 |
| Loss, May 29 to Sept. 23 | 6.65 | 2.39 | 1.19 | 2.50 |

The moisture content of the bare-surface plot exceeded that of the deep-mulch plot during the season and was about equal to that of the shallow-mulch plot. However, in considering the gain or loss of water on each plot, the difference in loss between the bare surface and deep mulch treatment was 1.31 percent in favor of the deep mulch.

The experiments just reported did not account for the difference in the amount of moisture absorbed by differently treated plots, due to the condition of the surface soil. Accordingly, in 1916, a series of plots similar to those in earlier experiments was laid out on which it was planned to retain all the water which fell upon them by means of earth dikes thrown up around their borders. Table 5 gives the data obtained from the diked plots.

Comparing these data with the results obtained from the undiked series in 1916, it is noted that the bare-surface plot gained slightly

more moisture than the deep-mulched or shallow-mulched plots where diked to insure equal absorption of rainfall upon all treatments.

TABLE 5.—*Moisture content (percentage of dry weight of soil) of diked plots variously treated at Manhattan, Kans., in 1916.*

| Date of sampling. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| April 17 | 18.05 | 20.20 | 18.36 | 16.77 |
| May 17 | 20.42 | 20.42 | 20.02 | 19.58 |
| June 17 | 20.48 | 22.20 | 20.55 | 20.04 |
| July 13 | 12.65 | 14.95 | 13.30 | 14.45 |
| August 12 | 14.33 | 19.40 | 14.60 | 16.40 |
| September 9 | 14.40 | 20.40 | 20.73 | 19.65 |
| Average | 16.72 | 19.59 | 17.92 | 17.81 |
| Gain or loss, April 17 to Sept. 9 | −3.65 | 0.20 | 2.37 | 2.88 |

The average gain or loss by the different treatments is summarized in Table 6, the moisture content of bare mulched plots being used as a basis of calculation.

TABLE 6.—*Gain or loss of moisture from plots variously treated at Manhattan, Kans., in 1914, 1915, and 1916.*

| Treatment. | Inches of water saved or lost by mulching. | | | | |
|---|---|---|---|---|---|
| | 1914. | 1915. | 1916. | | Average. |
| | | | Undiked. | Diked. | |
| Deep mulch | −0.37 | 0.11 | −0.23 | −0.10 | −0.130 |
| Shallow mulch | −0.48 | 0.00 | −0.01 | −0.50 | −0.242 |
| Weeds | −0.83 | −0.10 | −0.75 | −1.19 | −0.717 |

EXPERIMENTS AT GARDEN CITY.[13]

Experiments were begun at the Garden City station in 1912 to determine the effect of cultivation on the loss of water by evaporation from the soil.[14] The plots comprising this experiment were one-fortieth acre in size. They were irrigated each year during the winter as uniformly as possible in order to insure a high moisture content in the subsoil.

During 1912 and 1913 the plots received three different treatments: (1) cultivation 6 inches deep; (2) cultivation 3 inches deep; and (3) no cultivation, but the surface kept bare of vegetation with a hoe. The plots were located on level land and were diked to prevent sur-

[13] The work at Garden City is in cooperation with the Office of Dry-Land Agriculture, U. S. Department of Agriculture.

[14] Lill, J. G. Report of the Garden City substation, 1914. In manuscript.

face run-off and drainage water coming onto them. The soil was a silt loam with a deep subsoil. The water table at this elevation is located at about 75 feet. The subsoil was sufficiently porous to prevent saturation for any appreciable length of time.

The results secured in 1912 and 1913 are presented in Table 7.

TABLE 7.—*Moisture content of irrigated mulched and unmulched plots at Garden City, Kans., in 1912 and 1913, expressed in total inches of water in the upper 6 feet of soil.*

| Treatment. | 1912. | | | 1913. | | |
|---|---|---|---|---|---|---|
| | July 1. | October 10. | Gain or loss. | May 9. | Sept. 22. | Gain or loss. |
| 6-inch mulch | 17.89 | 17.56 | −0.33 | 18.52 | 17.88 | −0.64 |
| 3-inch mulch | 16.76 | 16.25 | −0.51 | 17.41 | 17.12 | −0.29 |
| Bare surface | 17.15 | 17.32 | 0.17 | 16.78 | 16.58 | −0.20 |

Comparing the inches of water gained or lost by the three surface treatments, the bare surface has gained 0.5 inch more than the 6-inch mulch and 0.68 inch more than the 3-inch mulch in the 1912 season. In 1913, the bare surface gained 0.35 inch more than the 6-inch mulch and 0.09 inch more than the 3-inch mulch.

In 1914 a series of dry-land plots was established. These were the same as the mulch plots established in 1912 but received no irrigation. A fourth plot upon which weeds were allowed to grow was added to the series. The results obtained from both the irrigated and dry-land plots in 1914 are presented in Table 8.

TABLE 8.—*Moisture content of irrigated and dry-land mulched and unmuched plots at Garden City, Kans., in 1914, expressed in total inches of water in the upper 6 feet of soil.*

| Treatment. | Irrigated plots. | | | Dry-land plots. | | |
|---|---|---|---|---|---|---|
| | March 30. | Sept. 16. | Gain or loss. | March 30. | Sept. 16. | Gain or loss. |
| 6-inch mulch | 17.59 | 15.87 | −1.72 | 11.78 | 12.35 | 0.57 |
| 3-inch mulch | 18.05 | 16.62 | −1.43 | 11.30 | 11.71 | 0.41 |
| Bare surface | 17.76 | 15.60 | −2.16 | 11.46 | 11.96 | 0.50 |
| Weeds | 16.41 | 9.06 | −7.35 | 10.75 | 8.03 | −2.72 |

The weeds occasioned a considerable loss of water from the soil. On the irrigated plots, there was a loss of 1.72 inches from the 6-inch mulch, 1.43 inches from the 3-inch mulch, and 2.16 inches from the bare surface. This is a difference of 0.44 inch of water in favor of the deep mulch and 0.73 inch in favor of the shallow mulch. The dry-land 6-inch mulch and bare surface plots gained approximately equal amounts of water. The 3-inch mulch gained 0.10 inch less, while the weeds caused a loss of 2.72 inches.

The average gain or loss with each treatment for each season is given in Table 9, data from the bare uncultivated plot being used as a basis for calculation.

TABLE 9.—*Average gain or loss of soil moisture from plots variously treated at Garden City, Kans., expressed in inches of water in the upper 6 feet of soil.*

| Treatment. | Irrigated. | | | Dry-land. | Average. |
|---|---|---|---|---|---|
| | 1912. | 1913. | 1914. | 1914. | |
| Deep mulch | −0.50 | −0.35 | 0.44 | 0.07 | −0.077 |
| Shallow mulch | −0.68 | −0.09 | 0.73 | −0.09 | −0.032 |
| Weeds | ......... | ......... | −5.19 | −3.22 | −4.200 |

During these years at Garden City the precipitation averaged 17.07 inches from January to January, being 18.74 inches in 1912, 23.58 inches in 1913, and 9.7 inches in 1914. Evaporation from a free water surface averaged 53.06 inches. The wind velocity averages about 10 miles per hour, although velocities of almost 30 miles per hour prevail at times in the spring for 24-hour periods.

It is evident from the data at hand, which were taken during seasons of severe climatic conditions, that a cultivated surface has not been more effective than a bare surface free of vegetation in preventing the loss of soil moisture by evaporation. They can lead to no other conclusion than that for Kansas conditions cultivation does not conserve moisture except as it eliminates weeds and checks surface run-off.

### EFFECT ON DEVELOPMENT OF PLANT FOOD.

The effect of cultivation on the development of plant food is often of more importance than the conservation of moisture. This phase of the problem was studied at Manhattan in 1914, 1915, and 1916, by determining the nitrates present in the differently treated plots previously mentioned. The determinations were made to a depth of 3 feet. The data are presented in Tables 10 and 11. The results are summarized in Table 12.

Table 10 shows that the bare-surface plot in 1914 contained the greatest amount of nitrates, with the 6-inch mulch plot second. This was a season of comparatively light precipitation (17.93 inches from January 1 to October 1), but the rainfall was evenly distributed.

The 1915 season was one of heavy precipitation, 44.97 inches falling from January 1 to October 1. This came principally in the months of May, June, and July. For this season the nitrate development, as shown in Table 10, was again greatest in the bare-surface plot, but

second in the plot having the 3-inch mulch. In such a rainy season, conditions less favorable to nitrification prevailed in the surface soil of the 6-inch mulch plot.

TABLE 10.—*Pounds of nitrates ($NO_3$) per acre in the upper 3 feet of plots variously treated at Manhattan, Kans, in 1914 and 1915.*

RESULTS IN 1914.

| Date of determination. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| April 5 | 264.38 | 194.76 | 328.29 | 233.39 |
| May 19 | 321.57 | 332.47 | 396.65 | 281.06 |
| June 4 | 179.61 | 407.87 | 579.34 | 465.22 |
| July 9 | 21.60 | 583.37 | 422.59 | 464.53 |
| July 23 | 32.84 | 527.72 | 878.86 | 812.48 |
| August 5 | 32.46 | 618.67 | 448.32 | 1,128.15 |
| August 25 | 41.57 | 712.53 | 456.79 | 859.28 |
| October 9 | 82.47 | 424.21 | 742.97 | 1,317.32 |
| November 2 | 142.87 | 678.70 | 697.55 | 853.65 |
| Average | 124.37 | 497.81 | 550.15 | 712.79 |
| Gain or loss | −121.51 | 483.94 | 369.26 | 620.26 |

RESULTS IN 1915.

| | | | | |
|---|---|---|---|---|
| April 15 | 83.43 | 471.04 | 276.83 | 552.80 |
| May 8 | 68.39 | 386.60 | 223.13 | 325.98 |
| June 16 | 43.92 | 515.57 | 247.40 | 704.90 |
| July 5 | 31.17 | 555.55 | 359.39 | 709.22 |
| July 27 | 32.38 | 492.52 | 328.71 | 637.37 |
| August 24 | 16.02 | 398.61 | 357.22 | 599.41 |
| September 8 | 19.87 | 651.68 | 484.26 | 971.82 |
| Average | 42.10 | 495.90 | 325.20 | 643.07 |
| Gain or loss | −63.56 | 180.64 | 207.43 | 419.02 |

In 1916, the months of July and August were very dry, although the precipitation from January 1 to October 1 amounted to 29.89 inches. In the diked plots, the average nitrates (Table 11) were greatest for the 6-inch dry mulch, yet during the dry months of July and August the nitrate contents of the bare-surface and 6-inch mulch plots were nearly equal. The average nitrate content of the plots receiving the bare-surface and the 3-inch mulch treatment were about equal. The data for the undiked mulch plots (Table 11) show the same results as those for the diked plots.

The 6-inch mulch treatment is superior to the bare surface, and the bare surface and 3-inch mulch are about equal in nitrate development.

TABLE 11.—*Pounds of nitrates ($NO_3$) per acre in the upper 3 feet of diked and undiked plots variously treated at Manhattan, Kans., in 1916.*

RESULTS FROM DIKED PLOTS.

| Date of determination. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| April 17 | 224.1 | 287.7 | 362.0 | 302.9 |
| May 17 | 219.0 | 174.3 | 385.5 | 251.8 |
| June 16 | 102.5 | 144.9 | 274.1 | 164.2 |
| July 13 | 123.5 | 372.7 | 478.3 | 465.9 |
| August 12 | 100.2 | 618.5 | 617.7 | 622.2 |
| September 9 | 158.3 | 531.5 | 624.6 | 445.7 |
| Average | 154.6 | 354.9 | 457.0 | 375.4 |
| Gain or loss | −65.8 | 243.8 | 262.6 | 142.8 |

RESULTS FROM UNDIKED PLOTS.

| | | | | |
|---|---|---|---|---|
| May 29 | 90.5 | 68.2 | 99.3 | 115.8 |
| July 1 | 58.3 | 246.5 | 452.5 | 327.9 |
| July 29 | 67.3 | 224.4 | 256.2 | 300.0 |
| August 26 | 66.7 | 343.0 | 553.5 | 424.0 |
| September 23 | 109.7 | 349.5 | 584.0 | 399.1 |
| Average | 78.5 | 246.3 | 567.8 | 313.3 |
| Gain or loss | 19.2 | 281.3 | 484.7 | 283.3 |

Table 12 presents annual and average data on the development of nitrates in the various plots from 1914 to 1916.

TABLE 12.—*Annual and average development of nitrates (pounds of $NO_3$) per acre in the upper 3 feet of plots variously treated at Manhattan, Kans., 1914 to 1916, inclusive.*

| Year. | Treatment. | | | |
|---|---|---|---|---|
| | Weeds. | 3-inch mulch. | 6-inch mulch. | Bare surface. |
| 1914 | 124.3 | 497.8 | 550.1 | 712.7 |
| 1915 | 42.1 | 495.9 | 325.2 | 643.0 |
| 1916[a] | 78.5 | 246.3 | 567.8 | 313.3 |
| Average | 81.6 | 413.3 | 481.0 | 556.3 |

[a] Diked plats not included.

The average development of nitrates for the 3 years has been greater in the bare, uncultivated plot than in the deep-mulch or shallow-mulch plots.

Determinations were made of the total nitrogen contained in the weeds for the season of 1916 in order to determine the amount of nitrification that had taken place in the weed plots. Converting the

total nitrogen into nitrates and adding it to the nitrates present in the upper 3 feet of soil of the weed plots gives the results shown in Table 13. This table indicates that as much nitrification took place in the weed plot as in the bare, uncultivated plot.

TABLE 13.—*Nitrification in weed plots, as indicated by the nitrates in the upper 3 feet of soil (in pounds of $NO_3$ per acre) plus the nitrates in the weeds on September 23, 1916.*

| Treatment. | Undiked. | Diked. |
|---|---|---|
| Cultivated 3 inches deep | 349.5 | 531.5 |
| Cultivated 6 inches deep | 584.0 | 624.6 |
| Bare surface | 399.1 | 445.7 |
| Weeds allowed to grow | 348.2 | 474.3 |

SUMMARY.

1. A cultivated soil is no more effective than a bare uncultivated soil in preventing evaporation.

2. Cultivation conserves soil moisture by the elimination of weeds and by preventing run-off.

3. The development of nitrates may be as extensive without cultivation as with cultivation.

# GREEN MANURING: A REVIEW OF THE AMERICAN EXPERIMENT STATION LITERATURE.[1]

A. J. PIETERS.

## INTRODUCTION.

The use of clover or of some other legume in the rotation is generally considered to be a cardinal agricultural practice in the humid sections of the United States. Without attempting to trace the development of this practice, which is an old one, it may be pointed out that in 1794 Thomas Cooper described a rotation of corn, wheat, clover two years, as being practiced by the best farmers in Pennsylvania. This is the most common rotation of today throughout the northeastern United States. The belief that clover was valuable as a soil improver rested first on experience and later, when the relation between the legumes and the nodule bacteria was discovered, men felt that the faith founded on experience had been justified by science.

Many researches were made in which the tops and roots of clovers were analyzed, the quantities of nitrogen stored determined, and conclusions drawn as to the degree to which the soil must be enriched by the growth on it of a vigorous crop of clover.

Other legumes have come into use in the territory not well adapted to red clover, as the cowpea, Japan clover, and bur clover in the South, and crimson clover on the Atlantic Coast. The main function of all these is to maintain fertility or improve run-down soils. If these crops really fulfill this function the result should be larger crops following the legumes and the experience of farmers seems to warrant the conclusion that such is the case. It has been the practice of the American experiment stations to test many, if not all, of the common beliefs of agriculture to find how well founded agricultural practice is and how improvements might be made if needed. That the value of clover or other legume in the rotation or as a green manure would be so tested was to be expected. Therefore, it has seemed worth while to examine the literature of American experiment stations and to bring together our knowledge of this subject with such critical comment as may be warranted.

[1] Contribution from the Office of Forage-Crop Investigations, United States Department of Agriculture. Publication authorized by the Secretary of Agriculture. Received for publication December 9, 1916.

The present inquiry concerns the evidence to be found in American experiment station literature on the value of a legume as measured by the yields of succeeding crops. The writer trusts that this point of view will be constantly borne in mind, as it is not his purpose to criticize methods or results. It is not always possible, however, to agree with the authors of bulletins as to the conclusions drawn.

In a general way a regional distribution of the literature may be made and this will at the same time be a distribution partially according to crops. In the South the rotation and green-manure work has been mostly with cowpeas, with a little on crimson clover, bur clover, sweet clover, and soybeans. In the North and Middle Atlantic States the experimental work has been nearly confined to crimson clover, while in the Northeast (including the Canadian Province of Ontario) and in the northern Mississippi Valley red clover has been the chief legume crop studied. Beyond the Missouri and in the Canadian Northwest, alfalfa, peas, tares, and species of Melilotus have been the chief leguminous green-manure crops.

The experiment station bulletins will be examined by States according to the above rough geographical division. Many of the bulletins treating of rotations or of green manuring are popular expositions of the principles involved and contain no original experimental work. Such bulletins do not, therefore, come within the range of this study. The same is true of bulletins, many of them valuable, that treat of the relations between legumes and the nodule organism (*B. radicicola*) or report the results of the study of the amounts of nitrates present after various crops. While such studies may have an important indirect bearing on the value of legumes they do not measure their value in terms of the succeeding crop and it is to this point of view that we shall mainly confine our attention. There are also bulletins and circulars from many stations containing the record of isolated observations. In order not to consume too much space such bulletins will be mentioned only when considered important. A full bibliography of the subject is, however, on file in the Office of Forage-Crop Investigations and if any reader believes an important paper has been overlooked he will confer a favor on the writer by advising him.

## Experiments in the South.

### ALABAMA.

The most important work with green manures in the South has been done in Alabama.

*Cotton.*—It was early shown (Canebrake Bul. 7 for 1890)[2] that

[2] Complete references to all publications cited are given in the bibliography at the end of the paper.

more cotton was produced on land immediately following cowpeas than on land on which peas had not been grown and that when the pea vines were turned under the yield of cotton was larger than when only the stubble was plowed under. The difference was not large, however, and the work appears not to have been repeated until several years later.

The West Alabama station (Report, 1903, p. 2) showed that by rotating cowpeas and cotton the yield of cotton was on the whole increased over that secured by continuous cotton culture, though during one year the yield of seed cotton after peas was actually less than that after cotton.

Further increases in the yield of both cotton and corn are reported as having been secured after peas, soybeans and sweet clover (Canebrake Bul. 24).

In Canebrake Bulletin 25 it is shown that the value of the cotton crop was increased by $8.68 per acre when a good stand of bur clover was turned under and by $7.08 per acre when a stand of crimson clover was used as green manure.

Canebrake Bulletins 26 and 27 (1910) contain records of an experiment on the yield of cotton after various crops. Two years' yields are reported in Bulletin 27 and the table is reprinted here as Table 1.

TABLE 1.—*Effect of legumes and nonlegumes on cotton grown on the Houston clay.*

| Cover crop in 1907 and 1908. | Pounds per acre of seed cotton. | | |
|---|---|---|---|
| | 1908. | 1909. | Total. |
| Cowpeas in 1908, vines turned under | — | 1,204 | 1,204 |
| Redtop (fair stand), whole turned under | 656 | 1,436 | 2,092 |
| White clover (good stand), whole turned under | 296 | 1,464 | 1,760 |
| Red clover, hay cut | 440 | 1,544 | 1,984 |
| Alfalfa, 17 months stand | Hay | 1,512 | 1,512 |
| Common vetch, hay cut | 760 | 1,312 | 2,072 |
| Common vetch and oats, hay | 416 | 1,436 | 1,852 |
| Oats, hay | 351 | 1,184 | 1,535 |
| Hairy vetch and oats, hay | 456 | 1,384 | 1,840 |
| Hairy vetch, cut | 752 | 1,512 | 2,264 |
| Crimson clover, cut | 868 | 1,344 | 2,212 |
| Bur clover, cut | 640 | 1,360 | 2,000 |
| No fertilizer, early cotton 1908–09 | 968 | 1,016 | 1,984 |

While the total yield of cotton for the two years 1908 and 1909 was higher after bur clover, crimson clover, and hairy vetch than from the check plot, the difference was not very great. The plots on which hairy vetch and oats and common vetch and oats had been grown and cut for hay as well as the white clover plot yielded less than the check.

The total yield from the redtop plot exceeded that from any legume plot save crimson clover and hairy vetch, but it should of course be remembered that a crop of hay was taken from the legume plots and not from the redtop. While the turning under of legume stubble seems to have resulted in an increase of cotton, a careful study of the figures shows some peculiarities that make it desirable that such a test be repeated. The check plot gave the highest yield of cotton the first year but the lowest the second year. This might be expected because of the possible temporary depressing influence of a green-manure crop. However, the plot on which oats was grown in 1907 gave the lowest yield of cotton in 1908 and the yield in 1909, though still lower than any plot having legumes turned under, was more than three times as heavy as it was in 1908. While some of the clover plots showed similar increases most of them did not. The red clover plot which yielded among the lowest in 1908 returned the largest crop in 1909, while the yield from the crimson clover plot in 1909 was the lowest but one from the legume plots, though in 1908 this plot had yielded more cotton than any other legume plot.

A considerable increase in the yield of seed cotton following alfalfa is reported in Bulletin 26, page 14, but since the comparison of the yield after alfalfa is made with that which the field had produced in previous years the observation has only minor significance.

The total yield of seed cotton grown for three years following the turning under of a crop of bur clover and one of crimson clover exceeded the yield from a plot continuously in cotton by about 500 pounds (Canebrake Bul. 27). It had been shown previously (Report, 1905, p. 35) that when cowpeas were fertilized and turned under the succeeding crop of seed cotton was increased by about 23 percent, but that on unfertilized land the cowpea crop was so poor that no increase in the cotton crop was noted.

Many of the experiments showing the effect of green manures on cotton have been brought together in Bulletin 120. In 1899 cotton followed cowpeas and velvet beans, the vines of which had been plowed under after the pods had been picked. The yields of seed cotton per acre were (p. 146):

| | |
|---|---|
| Following cowpea vines | 1,533 pounds. |
| Following velvet bean vines | 1,373 pounds. |
| Following cotton | 837 pounds. |

In another case (p. 151) cotton after velvet bean vines yielded 1,579 pounds per acre; after velvet bean stubble, 1,126 pounds; and after cotton, 918 pounds. The average gain in cotton from plowing under

the vines of summer legumes was 63 percent; from legume stubble, 18 percent.

The effect of turning under crimson clover was to increase the yield of cotton, as is shown below (Bul. 147):

| | |
|---|---|
| After oat stubble .......................... | 342 pounds seed cotton per acre. |
| After crimson clover stubble .............. | 456 pounds seed cotton per acre. |
| After crimson clover, entire ripe and dry crop plowed under ...................... | 528 pounds seed cotton per acre. |

*Corn.*—The effect of a green manure on corn was studied as early as 1887 (Bul. 7), though there is no record of a check plot for that year. After two years of Melilotus, corn yielded 7 bushels more than on the check plot (Canebrake Bul. 24). The results of a number of experiments showing the effect of a green-manure crop on corn are recorded in Bulletin 111. In 1900 corn was grown on plots on which velvet bean stubble, second growth or entire crop, and the entire crop of beggarweed had been turned under. The yields are compared with those from unfertilized plots on similar soil 100 yards distant. It seems possible that the experimental plots were naturally more fertile, since the yield from the unfertilized field was but 5 bushels an acre, while that from the experimental plots ranged from 15.6 to 27.5 bushels—a truly phenomenal increase if due entirely to the legume. Hairy vetch was compared with rye and turf oats as a crop to precede corn. The yields of corn in 1898 and 1899 were considerably better after the legume than after the nonlegume and a little better than on the plots left bare in 1897. Several peculiarities in the yields seem to point, however, to a lack of uniformity in the fertility of the plots. For instance, on plot 6 hairy vetch stubble was turned under and the yield of corn was 16.8 bushels. On plot 11 the vetch was a failure and the stubble of what grew was plowed in. The corn yielded 18 bushels on this plot. In 1899 plot 6 yielded 2 bushels per acre more than plot 11. On the whole the vetch was clearly beneficial in 1898 but the differences in yields during 1899 on all plots were not very marked.

In 1901 (Bul. 120 and 134) corn was grown on poor white sandy land, following corn or legumes. The yields were much higher after the legumes, reaching 81 percent increase on the plot on which velvet bean vines had been turned under.

In the summing up Duggar gives the average increase in the yield of corn following a summer legume, vines plowed in, as 81 percent, and stubble plowed in, as 32 percent.

*Oats.*—Red clover stubble increased the yield of oats by 15 bushels

per acre (Canebrake Bul. 25), while after white clover the increase was 6.3 bushels. Oats after cowpeas turned under yielded 22.8 bushels, while after millet the yield was 12.4 bushels (Bul. 95). In 1897 oats were sown on six plots on which cowpea or velvet bean vines, velvet bean stubble, German millet, or weeds had been turned under. The average yield of oats from the nonleguminous plots was 8.4 bushels; that from the legume plots, 32.6 bushels. It is admitted that these increases are probably greater than can ordinarily be expected. (Bul. 95, 120, and 137.)

In 1906 oats followed various crops. The yields following a legume were in every case much higher than the yields following corn. The addition of 60 pounds of nitrate of soda per acre on a plot previously in sorghum brought the yield of oats from that plot up to the average yield from all legume plots, but even the addition of 120 pounds of nitrate of soda did not bring the yield from the sorghum plot up to that from the plot on which the entire crop of soybeans had been turned under (Bul. 137).

*Sorghum.*—Sorghum for hay in 1897 yielded 85 and 86 percent more after cowpea or velvet bean vines turned under in 1896 than on a plot fallowed in 1896.

In 1899 the following yields of sorghum hay were obtained after various legumes (Bul. 120):

| | Yield per acre, tons. | Increase from legumes, tons. |
|---|---|---|
| After sorghum stubble | 3.65 | |
| After cowpea stubble | 5.66 | 2.01 |
| After velvet bean stubble | 5.80 | 2.15 |
| After cowpea vines, picked | 5.72 | 2.07 |
| After velvet bean vines | 6.76 | 3.11 |

The average increase in the yield of sorghum according to Duggar was 78 percent after summer legumes, vines turned under, and 57 percent after stubble turned under (Bul. 120).

Sorghum was also grown after rye stubble, crimson clover stubble, the entire crimson clover plant, and winter and spring weeds turned under. The yields were in every case much higher after the clover. In 1901, the average yield of two plots after rye stubble plowed under was at the rate of 5,992 pounds of green fodder, while the average yield after clover stubble plowed under was 11,230 pounds and the yield of one plot where the entire crimson clover plant was plowed under was 10,300 pounds. In 1903, sorghum after clover stubble yielded 13,000 pounds, while that after weeds yielded only 4,400 pounds (Bul. 147).

*Residual Effect of the Green Manure Crop.*—An important feature of the Alabama work is the record of the residual effect of the green manure crop. In some cases this was clearly marked up to the third season. On the sorghum plots of 1899 referred to above, corn was planted in 1900. The yields from the plots on which cowpeas and velvet bean vines had been turned under in 1898 exceeded the yield from the plot in sorghum in 1898 by 3.6 and 2.6 bushels per acre, respectively. The yield from the cowpea stubble plot was also a little higher than that from the sorghum plot, but on the velvet bean stubble plot the yield was slightly lower than that from the sorghum plot (Bul. 111).

In 1900 corn followed cotton on plots on which velvet bean vines were turned under in 1898. The land was poor and the plot in cotton for two years before 1900 yielded 18 bushels, while from the adjoining plot on which velvet bean vines had been turned under in 1898, 25.5 bushels of corn were harvested (Bul. 111 and 120). These plots in 1899 had yielded 1,578 pounds of seed cotton after velvet bean vines and 918 pounds after cotton, a difference of 660 pounds. In 1900 the difference in the corn yield was 7.5 bushels on the same plots (Bul. 120).

In 1901 corn followed corn of 1900 on legume plots (see p. 66). There is no record of a check plot here, but the yield from the plots on which the entire velvet bean vines had been turned under exceeded that from the stubble plot by 59 percent (Bul. 120). Some plots in cotton in 1899 (Bul. 120, p. 146) were put into sorghum hay and oats and sorghum hay as the next crops. A detailed financial statement (Bul. 120, p. 146) shows that the annual gain from turning under a crop of cowpeas in 1898 was $14.32 per acre or a total for three years of $42.96 more than was realized under similar conditions but where no legume had been grown for many years. All crops were larger on the legume than on the nonlegume plot even to the third year after turning under the legume.

Wheat and rye also showed marked increases after the turning under of a legume (Bul. 120).

*Relative Value of Turning Under the Stubble or the Entire Vine.*—There are a number of experiments throwing light upon this question. With the exception of wheat and rye, crops were uniformly larger after the vines were plowed under than after the stubble only was saved. That the value of this increase, $5.98 per acre, was not, however, equal to the value of the hay crop sacrificed is pointed out in Bulletin 120, page 172.

The record from this station shows that the yields of various field

crops were larger following the turning under of the stubble or of the entire crop of a legume than after another field crop. The cumulative effect of the large number of observations and experiments, all agreeing in the main, is unquestionably great. With the exception of redtop (Canebrake Bul. 27) and millet turned under (Bul. 95) no nonlegume was used as a green manure unless the weeds mentioned in Bulletins 95 and 120 be so considered. The entire crop of redtop gave slightly more favorable results than the stubble of most of the legumes used. The turning under of a crop of millet was followed by a crop of oats but little more than half as large as when a crop of cowpeas was turned under.

### ARKANSAS.

Rotation experiments commenced in 1890 are mentioned in Arkansas Bulletins 18, 22, and 27 and yields on two plots are given. From these it appears that when cowpeas were turned under the yield of cotton in two years was larger than that obtained from the continuous cotton plot in three years, and the first plot also yielded 22.4 bushels of corn per acre as the second of the three crops following cowpeas. Corn grown on plots after legumes and after nonleguminous field crops yielded larger crops after legumes. The average yield of five plots after cowpea stubble or peanuts was 36.8 bushels; after the cowpea vines turned under, one plot, 39.7 bushels; and after nonlegumes, cotton, corn, etc., the average of seven plots was 25.47 bushels (Bul. 46). The increased yield after cowpeas plowed under did not pay for the hay sacrificed, but there is no record regarding the residual effect of the cowpeas. Cotton also yielded 400 pounds more after a crop of cowpeas turned under than after cotton and 118 pounds more than after cowpea stubble (Bul. 46).

Wheat was grown on plots after cowpeas, velvet beans, beggar weed, and soybeans, each alternate plot being cut for hay and the stubble only turned under; the entire crop on the other plots was turned under. The first and the tenth plots were left as checks, wheat following wheat stubble. The turning under of the legume stubble increased the yield of wheat by 55 percent, but turning under the entire crop increased the yield over wheat stubble only 25 percent (Bul. 62). This depressing effect of turning under an entire crop was also noted under certain conditions at the Alabama station. In another case (Bul. 58) the yields of corn and of cotton were larger after the legume vines had been turned under than after the stubble. Nothing is said as to the yield of hay.

Oats followed various legumes turned under in 1900. Alternate

plots of oats were cut for hay and others for grain. The yields of both hay and grain were much higher after the legume than after oat stubble, the hay yield being nearly 60 percent and the grain nearly 50 percent greater after velvet beans. There were no legume stubble plots. Oats following cowpeas, soybeans, and rye and vetch plowed in also yielded much more than following corn, sorghum, buckwheat, or oat stubble with 400 pounds of complete fertilizer (Bul. 66). The author points out that the legume crop turned under would have made hay worth more than the value of the increased crops.

To test the relative value of cowpea stubble or the whole plant turned under seven plots, all in oats, were selected (Bul. 70). The average yield of the first three had been 21.84 bushels of oats; of the last four, 21.11 bushels. On the first three oats followed oat stubble. On 4 and 6 oats followed cowpea stubble and on 5 and 7 oats followed the cowpea vines turned under. The average yield of plots 1, 2, and 3 was 24.38 bushels; of plots 4 and 6, 28.84 bushels; and of 5 and 7, 37.02 bushels. Cowpeas seeded in corn increased the yield of corn the following season.[3]

The residual effect of cowpeas was studied between 1898 and 1903 (Bul. 77). On four out of thirteen plots cowpeas were planted following the 1898 wheat harvest and on two of them the whole plant was turned under, while only the stubble was used on the other two. Wheat was then grown for four years. The total yield on two check plots during the four years was 40.2 bushels; on the two stubble plots, 50.5 bushels; and on the plots on which the whole cowpea crop was turned under, 56.6 bushels. In the last years of the series the yields were respectively 10, 11, and 12.8 bushels as an average of both plots. The stubble gave the best increase the first year, while the benefit from the whole plant was most marked the second year and was decidedly noticeable the third and four years. On two other plots cowpeas were planted after wheat each year after 1899 and the yield on these plots increased each year, reaching an average of 17.2 bushels in 1902.

GEORGIA.

This station furnishes but one bulletin of importance on this subject (Bul. 27), but this contains the record of a remarkably clear and convincing experiment on the economic results of turning under a green crop or stubble. In 1893 and 1894 cotton was grown on plots in cowpeas the year before. On some plots the cowpeas were cut for hay, on others the peas were picked and the vines plowed

[3] Part of this information is repeated in the annual report for 1901.

under, while on still others the entire crop of peas, vines, and pods was plowed in. Record was kept of the value of the crops during both years of each test with the results shown in Table 2.

TABLE 2.—*Yields of cotton after cowpeas variously treated, with combined values of the cotton and cowpea crops.*

| Disposition of crop. | Yield of seed cotton per acre, 1894. | Total acre value of cotton, 1893, and hay and peas, 1892. | Total acre value of cotton, 1894, and hay and peas, 1893. |
|---|---|---|---|
| | *Pounds.* | | |
| Peas gathered when ripe ........ | 2,004 | $50.61 | $43.03 |
| Pea vines turned under green.... | 2,079 | 42.96 | 39.50 |
| Pea vines made into hay........ | 1,961 | 55.89 | 54.85 |

The residual value of the veins has not been taken into account. The work of the Alabama station showed that this might be considerable but whether enough to pay for the hay sacrificed can not be told.

MISSISSIPPI.

The Mississippi station found that by rotating crops and fertilizing the productive capacity of the land was increased 17 percent in three years, while under continuous culture of one crop the productive capacity of the soil was decreased 16 percent (Bul. 101). Eight years after a system of rotation was started, the yield of cotton on continuously cropped but fertilized land was 252 pounds of seed cotton per acre, while on rotated and fertilized fields the yield was 404 pounds. The rotation included cowpeas as a catch crop in the corn.

MISSOURI.

During three years of cropping with cowpeas, peas one year in four, and also sown in the corn at the last working, the yield of corn was somewhat larger the second and third years on the plots having a catch crop of cowpeas than on the check, but during the first year the cowpeas slightly depressed the yield (Bul. 83). The differences were small, however, in each year and the authors state that the fertility of the plots was not uniform. The differences may therefore have little significance. Wheat yields were less on the cowpea plots than on the checks in each of the two wheat years. The clover following wheat seemed benefited by the cowpeas in the second of the two years. On the whole the experiments did not lead to any definite conclusion.

In experiments in southwestern Missouri (Bul. 84) some plots received phosphorus and potassium while the adjoining plots had cow-

peas, phosphorus, and potassium. The yields of both corn and wheat were slightly less on the plots having the cowpeas. In an experiment in Jasper County (Bul. 119), cowpeas as a catch crop in corn did not increase the yields of corn, while the average yield of wheat was only very slightly increased.

Bulletins 126, 127, 128, 129, and 130 describe soil experiments on various soil types; plots receiving a cowpea catch crop in corn may be compared with the plots on which no legume was grown. In almost all cases the yields of corn were higher on the nonlegume plots, but those of wheat and oats averaged slightly better after the cowpea catch crop.

In Bulletin 131, the statement is made that as a result of 12 years' observations it may be concluded that the removal of cowpeas, where wheat and peas are both grown each year on the same land, results in a gradual decrease of the wheat crop. No details are given.

### NORTH CAROLINA.

In 1889 and 1890 this station raised wheat after cowpeas and after crabgrass. The plots were in duplicate and were repeated in 1890, making a very satisfactory experiment. Some plots were fertilized but in every case the crabgrass half of a plot received the same fertilizer as the cowpea half. On the unfertilized plots the yield of wheat on the cowpea half was double what it was on the crabgrass half, as an average of the two years. In 1890 the differences in yields were in some cases many times greater (Bul. 72, 77). It is said that the winter of 1889–90 was unusually severe and that winterkilling was especially bad on the plots that had not had cowpeas.

### TENNESSEE.

In connection with a fertilizer experiment it was shown that, on the unfertilized plots, cowpeas turned under increased the yield of wheat over that from plots from which the cowpeas were removed (Bul. 90). This was true in experiments on three farms. In Bulletin 96 these data are repeated and yields of wheat also given from areas on which no cowpeas had been grown. On one farm areas with and without cowpeas can be compared only on plots fertilized with acid phosphate and potash; the plots without cowpeas received a trifle more phosphate than the others. The yields of wheat were much better after cowpeas had been turned under than where no cowpeas had been grown. On another farm wheat was grown on unfertilized plots on which cowpeas had been turned under or removed and on

which no cowpeas had been grown. On the unlimed portions the cowpeas made no appreciable difference in the yield but where lime was added yields were best after cowpeas turned under and next best on plots from which they had been removed.

The value of cowpeas in building up land is brought out in Bulletin 102. A poor soil was planted to cowpeas in 1910 and in 1911. On one section, *C*, the crop was hogged off and on another, *D*, the vines were turned under for two years. In 1912 corn was grown. Though the yield of corn on similar and adjoining land was less than 10 bushels per acre that on the unfertilized plot of section *C* was 26.2 bushels and on *D*, 31.9 bushels. It is not shown whether it paid to turn under these two crops of cowpeas but it seems very probable that hogging off was more profitable.

In Bulletin 109 various statements are made but the present writer has not found the record of the evidence on which these are based. The conclusions appear, however, to be drawn from work done at the station and are as follows:

1. Corn, sorghum and millet are not suitable crops to be grown for green manure. The yield of corn immediately following them was considerably reduced. Rye is advised as a winter cover crop, but should be turned under early, when about 1 foot high, or less.

2. The legumes can be advised as green-manure crops, but cowpeas and soybeans when used for this purpose are not apt to be profitable for the first few years. If turned under each year and followed with wheat or other small grain, as can be done successfully at Jackson, the effect is cumulative; that is, the area where the cowpeas are turned under gradually increases in productiveness, while the area where either the peas are removed for hay or no peas are grown gradually becomes poorer until the difference between them is very marked. In the last two years of a 5-year trial there were obtained from 4 to 9 bushels per acre more of wheat on the area where the cowpeas were turned under than where either none were grown or the crop was removed for hay.

Sweet clover sown April 11, 1912, was cut once that year for hay. The crop was turned under May 13, 1913, and followed with corn, which made a yield of 58.8 bushels per acre. On an adjoining plot where rye was turned under, the yield of corn was only 41.1 bushels.

### SUMMARY.

While it must be said that for the greater part the record above reviewed is that of a series of observations rather than of carefully planned and checked experiments it can not be denied that the observations, all pointing in one direction, make a strong case for the value of leguminous green manure or rotation crops. The evidence

will not, however, warrant more than this general statement. On important matters of detail, especially as to the relative value of different legumes and the effect they may have on the succeeding crop, the record throws no light. For the most part this is because little work has been done with any plant save the cowpea. Only the Alabama station worked with winter legumes, and the value, if any, of nonlegumes for green manuring has practically not been touched upon. The question whether it pays to turn under an entire green legume crop has been taken up and it has been shown both by Alabama and Georgia that, considering only the first succeeding crop, the practice is not economical. Alabama showed, however, that cowpea and velvet bean vines turned under have a definite and considerable residual value, but the number of cases in which it is possible to compare the residual value of stubble or of vines are too few to warrant conclusions. This was also shown for cowpeas by Arkansas. This matter is important and it is to be hoped that experiments are under way, or will be undertaken, to determine this point definitely.

The following statements are believed to be warranted by the experiments reported in the literature reviewed:

1. The turning under of a leguminous crop or of the stubble and residues of such a crop results in an increase, sometimes large, in the next succeeding crop.

2. Turning under a heavy crop of green plants, especially under conditions of dry weather or of imperfect working of the soil, may depress yields below those obtained from turning under the stubble only.

3. Cowpeas grown as a catch crop in corn may depress the yield of the corn. This seems to be due to lack of moisture.

4. The residual effect of whole crops of cowpeas and velvet beans turned under is marked, while that of the stubble is sometimes evident, but slight.

5. Considering only the effect on the first succeeding crop it is not profitable to turn under a full stand of green manure.

## Atlantic Coast Section.

With the exception of a little work showing the influence of alsike and of red clover on potatoes, the work of the stations in this section has been almost entirely with crimson clover. One green manure crop of cowpeas was tried by the Maryland station and the New Jersey station records some work with cowpeas and soybeans.

### CONNECTICUT.

The Connecticut (Storrs) station (Storrs Reports, 1899 and 1900) grew potatoes in 1900 on land on which alsike clover had been seeded in July, 1899, and on land on which rye had been seeded after corn harvest. When turned under the clover was 3 inches and the rye 3 feet high (Report, 1900, p. 63). The yield of potatoes on the clover plot, 183.1 bushels of good potatoes, was considerably higher than that on the plot having rye and mineral fertilizers, 151.4 bushels, but also exceeded that on the plot having clover plus mineral fertilizers, 177.8 bushels. The difference in this case is not large but would appear to indicate a lack of uniformity in the fertility of the soil of the experimental area. Many details of the work are wanting and so far as known the experiment was not repeated.

### DELAWARE.

The Delaware station has issued a number of bulletins on crimson clover, green manure, and orchard cover crops, but in only two cases is there any record of an experiment to determine the effect of crimson clover on a subsequent crop. A complete fertilizer including 160 pounds of nitrate of soda per acre was applied to one plot in June, 1890, while the crimson clover from $1 worth of seed was turned under on another plot in May. Sweet potatoes were planted on all plots. The yield on the clover plots was 18 bushels per acre more than on the fertilized plots and 103 bushels more than the average of five unfertilized plots (Bul. 11). In the report for 1892 the yield of corn on a plot on which a heavy crop of crimson clover had been turned under is compared with that on adjacent land on which tomatoes had been grown. The corn on the latter plot received 100 pounds of nitrate of soda per acre, but still the yield was 18 bushels less than that from the clover plot. So far as known this experiment was not repeated.

### MARYLAND.

The Maryland station in Bulletins 31 and 38 records yields of potatoes after crimson clover. In one case a small increase, and in the other a 50 percent increase was found to result from turning under a green manure crop of crimson clover. In each case the results are for one year only. In 1895 the yield of corn on plots on which crimson clover had been turned under was 6.7 bushels per acre more than that on adjacent plots not having received crimson clover (Bul. 46). The yield of corn on these plots in 1896 after a second crop

of clover had been turned under was larger than the 1895 yield, but the yield of plots not having clover is not given for 1896, so it is not possible to say whether the added increase was due to season or to the extra clover.

In an experiment on the availability of different forms of phosphoric acid, plots were laid off receiving the same fertilizers but some of them having crimson clover seeded at the last working of the corn, others rye after the corn, and others left bare over winter (Bul. 68). The total yield of corn for 1895 on the crimson clover plots was less than that on the rye or on the bare plots, indicating that the fertility of the soil was less on these plots. In 1897, however, after two catch crops of clover and of rye had been turned under the yield of corn on the clover plots was 35 percent higher than on the bare plots and 58 percent higher than on the rye plots. In 1898, owing to early summer drought, wheat was sown instead of corn, the plots being fallowed for that season. There was no great difference in the wheat yields, those from the clover plots being slightly smaller. This work was continued through the crop of 1906 and the results reported in Bulletin 114. The results during the latter half of this experiment make it necessary to reverse the conclusions drawn from Bulletin 68, since the average yields on the rye plots during the years 1902–1906 were better than on the crimson clover plots. The average yield of corn on the fallow plots and on those where crimson clover and rye were turned under were as follows:

| | 3 crops, 1895–1897. | 3 crops, 1902–1906 |
|---|---|---|
| After crimson clover | 45.9 bushels. | 34.3 bushels. |
| After fallow | 45.0 bushels. | 34.2 bushels. |
| After rye | 42.2 bushels. | 40.3 bushels. |

This showing is really too favorable to the clover, since some of the clover plots had soluble phosphates while the others did not. The average yield of six crops of corn, two of wheat, and three of hay on all plots to which insoluble phosphates were applied were as follows:

TABLE 3.—*Average yields of corn, wheat, and hay after crimson clover, after rye, and after fallow.*

| | Corn, bus. | Wheat, bus. | Hay, pounds. |
|---|---|---|---|
| After crimson clover | 39.4 | 19.8 | 3,500 |
| After fallow | 39.4 | 20.8 | 3,866 |
| After rye | 41.8 | 23.7 | 4,211 |

The author suggests several reasons to explain the failure of clover to equal the rye, among them being the poor growth of the clover in recent years due to weather conditions.

Cowpeas were planted in 1896 and plowed under on limed and on unlimed plots. A rotation of wheat, hay, corn, followed. The wheat on the cowpea plots was much larger than on the check plots (Bul. 110, p. 9).

### MASSACHUSETTS.

A special bulletin on green manuring by Dr. Julius Kuhn was issued in 1894, but the experiments discussed were all conducted in Germany.

In certain other experiments potatoes were grown on clover sod, after one year of soybeans, and on land which had annually received a good dressing of nitrogenous fertilizer. All plots received annually equal applications of phosphoric acid, potash, and lime, but the clover land had received no nitrogenous fertilizer for 16 years. The yield of potatoes on the clover sod was almost as large as that on the fertilized plots and besides two cuttings of clover hay had been taken from this land. Soybean stubble did not improve the yield of potatoes and the yields of oats and rye, which were grown for some years alternately with soybeans, steadily declined (13th and 16th Ann. Rpts.. pp. 94 and 123, respectively). Soybeans did not improve the fertility of the soil as measured by the yield of oats in an experiment summarized in the 9th Annual Report, pp. 176–177.

### NEW JERSEY.

At the New Jersey station (Reports, 1912 and 1913) corn or oats were grown on land on which green manure catch crops of rye and of crimson clover or vetch had been turned under each year from 1908 to 1912. The yields of corn for 1909, 1911, 1912, and 1913, and of oats for 1910 were in every case conspicuously larger after crimson clover or vetch than after rye.

An experiment on using cowpeas as a summer catch crop with rye and with wheat was carried on for five years, 1909–1913 (Report, 1912, p. 261, and Report, 1913, p. 473). The wheat crop of 1909 before any legume had been used was 19.6 bushels on the plot without legume and 31.07 bushels on the legume plot, while the average yield of wheat for the four following years was 11.87 and 19.51 bushels respectively. While it is true that during each of these years the yield of wheat on the legume plot was higher than that on the nonlegume the difference was scarcely more than that which existed between the plots when the experiment began. The yields on these plots for 1914 are given in Bulletin 281 and it appears that the legume plots continue to return the largest yields.

On the rye plots the effect of the legume is more marked. If, however, the crop of 1910 instead of the one for 1909 is chosen as a

basis for comparison, the effect of the legume on the wheat crop becomes more evident. The crops for 1910 were preceded by a very poor stand of cowpeas, and on the legume plots the yield of wheat was but little more than that on the nonlegume plot, while the yield of rye was even less on the legume than on the nonlegume plot. In every subsequent year the crops on the legume plots were markedly higher than on the nonlegume plots.

A comparison of the amount of dry matter in a corn crop following crimson clover stubble or the entire crop turned under is made in the Report for 1894, p. 135. The yield of crude fat, fiber, protein, ash, and carbohydrates in the corn was greater where the entire clover crop had been turned under, but the total food secured from the land, including clover and corn, was greater when only the stubble was turned under.

In the 35th Annual Report, pages 223–226 (1914), Lipman and others report that the yield of rye was nearly a fourth more after legumes than on plots without legumes and that the yield of wheat was more than doubled. The percentage of nitrogen recovered was also higher in the grain crops from the legume plots.

In the course of an experiment to determine whether ground limestone aids in the decomposition of organic matter, green alfalfa, timothy, oats, and peas were chopped fine and added to soil in pots (Report, 1914, p. 217). To other pots nitrate of soda was added, while the check pots as well as all others received equal amounts of mineral fertilizer. Buckwheat was used as the indicator crop. On the pot to which alfalfa had been added the amount of dry matter produced was nearly as great as on the pot to which the nitrate of soda was added, while the amount of dry matter on the timothy and on the oats and pea pots was greater than that from the check pots but did not equal that from the alfalfa pots.

This station has also conducted a number of cylinder experiments in which leguminous crops were grown and turned under for a succeeding crop. The yields of rye and corn were larger after crimson clover and hairy vetch had been turned under in the soil on which these legumes were grown, than on soil on which legumes had not been grown but to which an equivalent amount of green legumes had been added (Bul. 250). More nitrogen was also recovered in the corn crop in the former case. Further cylinder experiments are reported in Bulletins 288 and 289. Oats yielded better in 1909 and 1910 after hairy vetch than in cylinders without legumes (Bul. 288).

Crop rotations were conducted in 320 cylinders (Bul. 289) on one series of which green manure catch crops were used according to the following plan: Corn followed by crimson clover; potatoes followed by cowpeas and vetch; oats with cowpeas or soybeans between oats and rye, which was again followed by cowpeas or vetch. Another series of cylinders received stable manure at the rate of 15 tons per acre every two years; a third series received nitrate of soda at the rate of 160 pounds per acre. All received lime and mineral fertilizers and of two other series one received only lime and a second lime and mineral fertilizers.

The amount of dry matter in the crops on the green manure series was much larger than that from any of the other series. Studies were also made of the amounts of nitrogen removed in crops and the amount left in the soil at the conclusion of the experiments. While the amount of nitrogen in the soil at the end (1912) was less than at the beginning (1907) in almost all cases this loss was least in the green manure series and from this series the largest amount of nitrogen had been removed in the crops (pp. 29–31).

While the effect of the association of a legume and nonlegume, strictly speaking, is not included in the present study, its bearing upon the value of a legume is evident and a brief statement of the literature on the subject will be included therein. Since the most important single contribution has been made by the New Jersey station, the entire literature will be reviewed here.

In 1911 Lyon and Bizzell (Cornell Bulletin 294) gave analyses of timothy growing with and without alfalfa and of oats growing with and without Canada field peas. It was shown that the nonleguminous crop grown with the legumes contained a markedly higher protein content than that grown without.

In Bulletin 253 of the New Jersey station (1912), Doctor Lipman reviews the older literature on the subject, criticizes the method adopted by Lyon and Bizzell, and reports extensive experiments made by the New Jersey station between 1908 and 1911. These experiments consisted of growing legumes and nonlegumes in cylinders, in pots in the greenhouse, and in some cases in field plots, in which case the nonlegume was grown both alone and in association with a legume. To determine whether or not nitrates pass by diffusion from the legume to the nonlegume, Doctor Lipman used small pots, in some cases glazed and in others unglazed, sunk in the soil contained in a larger pot, the legume being grown in the one and the nonlegume in the other. As a result of his experiments Doctor Lipman concludes that under favorable conditions nonlegumes associated with legumes

may secure large amounts of nitrogen from the latter, even though this may not be indicated by an increased proportion of nitrogen in the dry matter of the nonlegume. In the field experiments no satisfactory results were obtained. In some cases the yield of the nonlegume was depressed because of the presence of the legume. This is ascribed to lack of moisture.

A part of this experimental work had already been reported by Lipman (Jour. Agr. Sc., 3: 297) and a further discussion in regard to the methods and the priority of the work was entered into by Doctors Lyon and Bizzell and Doctor Lipman in the Journal of the American Society of Agronomy (Vol. 5, No. 2, pp. 65–82. 1913). In Bulletin 253 of the New Jersey station Doctor Lipman quotes from Bulletin 61 of the South Carolina station to show that the beneficial effect of peas on the yield of corn has been noted by that station. The present writer has, however, been unable to find that the statement made on page 8 of Bulletin 61 of the South Carolina station is justified by the yields reported. It is stated that the yield of corn was increased, particularly on plot 4. Examination of the yields, however, shows that during 1898 the yield on plot 4 was less than 0.4 bushel more than that of the average on all the plots in the experiment, and in 1899 the yield on plot 4 was actually less than the average of the other plots.

Westgate and Oakley (Jour. Amer. Soc. Agron., 6:210–215. 1914) report the analyses of a number of grasses growing with and without a legume. They conclude that the data presented are not sufficient to warrant the statement that a nonlegume growing with the legume will have an increased content of protein.

At the Virginia station an experiment was conducted on the effect of the association of legumes and nonlegumes (Va. Technical Bul. 1, April, 1915). The authors show that bluegrass growing with white clover and timothy growing with red clover did not contain more protein than when growing without, except that in the second year of the experiment the timothy growing with clover contained more protein than when growing without clover, but this may well have been the effect of the preceding year's growth of clover. Corn, when grown with beans, produced a greatly increased crop and the percentage of nitrogen was also much larger when the corn was grown with beans than without. In the field experiment, however, corn grown with beans gave a lower yield than when grown without. The authors consider that the decreased yield in this case was due to the lack of moisture.

Evans (Jour. Amer. Soc. Agron., 8:348–357. 1916) has recently shown that bluegrass and timothy growing with clovers have a higher

protein content than when growing alone on check plots and also that the growth of grasses made between clippings when grown with clover exceeded that of grass grown alone by some 21 percent.

### RHODE ISLAND.

Beginning with 1898 crimson clover was seeded between certain rows of blackberries and of blackcaps at the Rhode Island station, while other rows were left blank (Bul. 91). The crops of berries in 1901 and 1902 were about twice as large on the rows receiving crimson clover as on the check rows.

In 1896 an experiment was started on growing corn continuously with clover and with rye as green manures. The total yield of hard corn for nine years, 1897 and 1905, inclusive, on the clover plot was 378 bushels per acre and on the rye plot, 312.2 bushels. Beginning with 1898 the plots were divided so that some remained fallow. The yields on the fallowed sections averaged a little less than on the rye and much less than on the clover. From 1898 to 1902 there was a progressive improvement on the clover plot, as measured by the corn yield (Bul. 113).

A series of rotations was planned in 1893 (Ann. Rpt., 1893, p. 176), in one of which a legume replaced timothy and redtop, rotation *B*; while rotations *E* and *F* were alike except that rye was used as a cover crop in *F*, and a legume was used in *E*.

In the annual report for 1897 it is shown that the yield of potatoes following clover sod on rotations *A* and *C* exceeded that following corn on rotations *B, D, E,* and *F* by nearly 55 bushels. This increase consisted, however, almost entirely of small potatoes, the yield of large ones being only 1½ bushels more after clover sod than after corn. Potatoes followed grass and clover sod on rotation *C* and followed corn on rotation *D*. In Bulletins 74 and 75 the yields of potatoes for the first and second courses of these rotations are reported. The yield on *C* (grass and clover sod) was less than 1 bushel per acre greater for the two courses than from *D* (after corn, following grass and clover sod).

Rotations *E* and *F* are discussed in Bulletin 76, in the Annual Report for 1902, and in Bulletin 167. In the latter the yields for the entire period of 20 years have been brought together. These rotations were alike save that clover was seeded with the timothy in *E* and not in *F*, and that legumes, crimson clover and hairy vetch, were seeded at the last working of the corn on rotation *E* while rye was used on *F*.

The average yield of corn and potatoes on all plots of these two

series for 20 years, extracted from tables on pages 14 and 19 of Bulletin 167, are as follows:

| | Rotation E, bushels. | Rotation F, bushels. |
|---|---|---|
| Corn (hard) | 56 | 53 |
| Potatoes | 119 | 216 |

This shows no benefit, under the conditions obtaining at the Rhode Island station, from using a legume rather than grass or rye. Attention must be called, however, to the fact that on the continuous corn acre a leguminous cover crop gave better returns than rye (Bul. 113).

### SUMMARY.

Potatoes and corn have been the chief indicator crops of this section, with wheat and oats of very minor importance. Crimson clover has been the chief green manure crop, red and alsike clover, cowpeas and vetch having been occasionally used. The records include carefully controlled experiments and observations of small value, but the results are in general agreement as showing that a legume benefits the following crop of corn or potatoes, especially the latter.

The addition of nitrogenous fertilizers did not always bring the yield on the nonlegume plot up to that from the legume plot.

Rye was compared with clover as a green manure crop to precede potatoes and corn by the Connecticut, Maryland, and New Jersey stations and the clover was generally found to be superior.

The entire clover crop turned under was found by the New Jersey station to yield a crop of corn containing more protein, fat, and carbohydrates than a corn crop on clover stubble, but the total amount of these feeding stuffs obtained in the two years was much greater when the clover was used for hay.

*(To be continued in the next number.)*

## A LIMESTONE TESTER.[1]

CYRIL G. HOPKINS.

The writer has designed a simple apparatus, by means of which the relative purity of limestone can be quickly ascertained with a very satisfactory degree of accuracy, the determination being based upon the basicity, or carbon dioxid content. As shown in figure 4, this limestone tester consists of two small glass bottles, joined together

[1] Contribution from the Department of Agronomy and Chemistry, College of Agriculture, University of Illinois. Received for publication November 18, 1916.

and fitted with ground-glass stoppers, the stopper of the smaller bottle resting upon a surface only slightly inclined from the horizontal, and projecting loosely into the neck, thus serving as a valve.

To make the test, place 5 grams of pulverized limestone in the larger bottle and fill the smaller one to the side opening with acid made by mixing about equal parts of concentrated hydrochloric acid and water and saturating with carbon dioxid. Insert the stoppers and weigh. Now tip the apparatus carefully until the acid begins to flow through the side opening. As it drops upon the limestone, the carbonate is changed to chlorid and the liberated carbon dioxid gas passes through the side opening, lifting the small stopper as it passes out. Partly immerse the apparatus in cool water to keep it at about room temperature. Gradually transfer the acid until foaming ceases; then dry the apparatus with a soft cloth, weigh, and note the loss. To this loss in weight add about 0.6 milligram for each cubic centimeter of air space in the loaded apparatus (see Tables 2 and 3), then deduct the proper percentage for the room temperature (about 1 percent for 20° C.—see Table 1), and divide by 2.2 to get the relative purity of the stone.

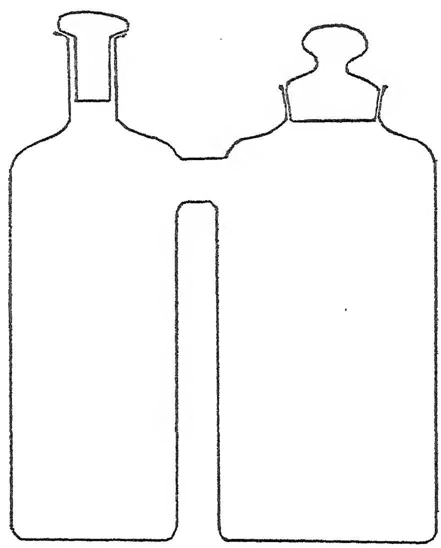

FIG. 4. Apparatus used in testing limestone. Weight, about 40 grams; capacities below connecting tube, about 35 and 40 cc., respectively

If the direct loss represented only the total carbon dioxid liberated, then its weight divided by 2.2 would give the relative purity of the stone in terms of calcium carbonate, since 5 grams of pure calcium carbonate contains 2.2 grams of carbon dioxid.

However, the moist air which fills the air space at the beginning is replaced by moist carbon dioxid during the reaction. At 20° C. and 745 millimeters barometric pressure (taken as room temperature and average atmospheric pressure at an elevation of 600 feet above sea level), 1 cubic centimeter contains 1.754 milligrams of carbon dioxid or 1.154 milligrams of air, not including the water vapor. The

difference in weight is 0.6 milligram per cubic centimeter; and, if the air space in the loaded apparatus is, for example, 75 cubic centimeters, then, under these conditions, 45 milligrams should be added to the loss in weight.

Again, the gas (air or carbon dioxid) passing out of the apparatus during the reaction is accompanied by some water vapor, which amounts to .017 milligram per cubic centimeter at 20° C. The combined weight of the carbon dioxid and water vapor in 1 cubic centimeter, at 20° C. and 745 mm., is 1.771 milligrams (1.754 + .017). Thus, under these conditions, about 1 percent must be deducted from the first corrected weight.

For example, 5 grams of a certain limestone shows a loss of 1.99 grams. The first correction (45 milligrams) increases this to 2.035 grams, and the second correction (20 miligrams) reduces it to 2.015 grams. This divided by 2.2 gives 0.916, or 91.6 percent, as the relative purity of the stone.

For most practical purposes, the first correction is a constant for each apparatus, the variations for ordinary differences in temperature and pressure being negligible; and the second correction varies significantly only with change of temperature. Thus, if the room temperature is 30° C., add to the weight of escaped gas 0.6 milligram per cubic centimeter of air space and then deduct 1.74 percent (see Table 1). This, in the above example, with a direct loss of 1.99 grams, would give a final corrected weight of 2 grams of carbon dioxid from 5 grams of stone, and this divided by 2.2 gives 90.9 percent. But, to perform the operation at 30° and compute the second correction at 1 percent, as should be done for 20°, would introduce an error of 0.7 percent in the purity found.

To saturate the hydrochloric acid with carbon dioxid, drop a piece of limestone weighing 3 or 4 grams into a 500 c.c. bottle of the diluted acid, replacing the stopper after foaming ceases. To determine the air space in the loaded apparatus, place 5 grams of pulverized limestone in the larger bottle, fill the smaller bottle to the side opening with water, and then pour in measured water from a graduated cylinder and note the addition required to completely fill the apparatus. The vapor pressure of the dilute hydrochloric acid used is negligible, corresponding to less than 1 milligram of HCl per liter.

A set of weights from 5 milligrams to 50 grams, a balance suitable for these weights with a capacity of 100 grams, a thermometer, a 25 c.c. graduated cylinder, and the limestone tester, are all one needs for determining the relative purity of limestone for use in neutralizing acidity, as in soil improvement. If one also has a barometer and a balance capable of weighing to 1 milligram, a still higher degree of

accuracy may be secured by using the data given in the accompanying tables.

Thus, 5 grams of a pulverized limestone shows a direct loss of 2.164 grams at 25° C. and 724 mm., with an apparatus having 71 cubic centimeters air space when loaded. When saturated with water vapor under those conditions, 1 cubic centimeter contains 1.659 milligrams of carbon dioxid or 1.093 milligrams of air, the difference being 0.566 milligrams, or 40 milligrams in 71 cubic centimeters. This first correction being added gives 2.204 grams of moist carbon dioxid, of which 1.29 percent, or 28 milligrams, is water vapor, leaving 2.176 milligrams of dry carbon dioxid, and this divided by 2.2 gives 98.9 percent; whereas, if the barometric pressure were assumed to be 745 mm., the purity found would be 99.0 percent, as may readily be computed from the data given in Tables 1, 2, and 3. (Tables 1 and 3 are computed from basic data given in Castell-Evans' Physico-Chemical Tables, I, 341; and Table 2 is Parr's table extended to include the higher summer temperatures.)

TABLE 1.—*Carbon dioxid saturated with water vapor at 760 millimeters (29.92 inches).*

| Temperature. | | Milligrams per cubic centimeter. | | | Percentage of water in total. | Pressure of water vapor, mm. |
|---|---|---|---|---|---|---|
| °C. | °F. | Carbon dioxid. | Water vapor. | Total. | | |
| 10 | 50.0 | 1.879 | 0.009 | 1.888 | 0.50 | 9.2 |
| 11 | 51.8 | 1.870 | .010 | 1.880 | .53 | 9.8 |
| 12 | 53.6 | 1.862 | .011 | 1.872 | .57 | 10.5 |
| 13 | 55.4 | 1.853 | .011 | 1.864 | .61 | 11.2 |
| 14 | 57.2 | 1.844 | .012 | 1.856 | .65 | 11.9 |
| 15 | 59.0 | 1.836 | .013 | 1.848 | .69 | 12.7 |
| 16 | 60.8 | 1.827 | .013 | 1.840 | .73 | 13.5 |
| 17 | 62.6 | 1.818 | .014 | 1.832 | .78 | 14.4 |
| 18 | 64.4 | 1.809 | .015 | 1.824 | .83 | 15.4 |
| 19 | 66.2 | 1.800 | .016 | 1.816 | .89 | 16.3 |
| 20 | 68.0 | 1.791 | .017 | 1.808 | .95 | 17.4 |
| 21 | 69.8 | 1.782 | .018 | 1.800 | 1.01 | 18.5 |
| 22 | 71.6 | 1.773 | .019 | 1.792 | 1.08 | 19.7 |
| 23 | 73.4 | 1.763 | .020 | 1.784 | 1.15 | 20.9 |
| 24 | 75.2 | 1.754 | .022 | 1.776 | 1.22 | 22.2 |
| 25 | 77.0 | 1.744 | .023 | 1.767 | 1.29 | 23.6 |
| 26 | 78.8 | 1.735 | .024 | 1.759 | 1.37 | 25.0 |
| 27 | 80.6 | 1.725 | .026 | 1.751 | 1.46 | 26.5 |
| 28 | 82.4 | 1.715 | .027 | 1.742 | 1.55 | 28.1 |
| 29 | 84.2 | 1.705 | .029 | 1.734 | 1.64 | 29.8 |
| 30 | 86.0 | 1.695 | .030 | 1.725 | 1.74 | 31.5 |
| 31 | 87.8 | 1.685 | .032 | 1.716 | 1.85 | 33.4 |
| 32 | 89.6 | 1.674 | .033 | 1.707 | 1.96 | 35.4 |
| 33 | 91.4 | 1.664 | .035 | 1.699 | 2.08 | 37.4 |
| 34 | 93.2 | 1.653 | .037 | 1.690 | 2.20 | 39.6 |
| 35 | 95.0 | 1.643 | .039 | 1.682 | 2.34 | 41.8 |

TABLE 2.—*Weight of dry carbon dioxid in milligrams per cubic centimeter of saturated gas at various temperatures and various barometric pressures.*

(Corrected for water vapor, etc.—Parr's Table: Jour. Amer. Chem. Soc., 31 : 237.)

| °C. \ mm. | 720 | 722 | 724 | 726 | 728 | 730 | 732 | 734 | 736 | 738 | 740 | 742 | 744 | °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 1.779 | 1.784 | 1.789 | 1.794 | 1.799 | 1.804 | 1.809 | 1.814 | 1.819 | 1.824 | 1.829 | 1.834 | 1.839 | 50.0 |
| 11 | 1.771 | 1.776 | 1.781 | 1.786 | 1.791 | 1.796 | 1.801 | 1.806 | 1.811 | 1.816 | 1.820 | 1.825 | 1.830 | 51.8 |
| 12 | 1.762 | 1.767 | 1.772 | 1.777 | 1.782 | 1.787 | 1.792 | 1.797 | 1.802 | 1.807 | 1.812 | 1.817 | 1.822 | 53.6 |
| 13 | 1.754 | 1.759 | 1.764 | 1.769 | 1.774 | 1.779 | 1.784 | 1.789 | 1.794 | 1.799 | 1.804 | 1.809 | 1.813 | 55.4 |
| 14 | 1.746 | 1.751 | 1.756 | 1.761 | 1.765 | 1.770 | 1.775 | 1.780 | 1.785 | 1.790 | 1.795 | 1.800 | 1.805 | 57.2 |
| 15 | 1.737 | 1.742 | 1.747 | 1.752 | 1.757 | 1.762 | 1.767 | 1.772 | 1.777 | 1.782 | 1.786 | 1.791 | 1.796 | 59.0 |
| 16 | 1.729 | 1.734 | 1.739 | 1.744 | 1.748 | 1.753 | 1.758 | 1.763 | 1.768 | 1.773 | 1.778 | 1.783 | 1.788 | 60.8 |
| 17 | 1.720 | 1.725 | 1.730 | 1.735 | 1.740 | 1.745 | 1.750 | 1.755 | 1.759 | 1.764 | 1.769 | 1.774 | 1.779 | 62.6 |
| 18 | 1.712 | 1.717 | 1.722 | 1.726 | 1.731 | 1.736 | 1.741 | 1.746 | 1.751 | 1.756 | 1.760 | 1.765 | 1.770 | 64.4 |
| 19 | 1.703 | 1.708 | 1.713 | 1.718 | 1.723 | 1.727 | 1.732 | 1.737 | 1.742 | 1.747 | 1.752 | 1.756 | 1.761 | 66.2 |
| 20 | 1.694 | 1.699 | 1.704 | 1.709 | 1.714 | 1.719 | 1.723 | 1.728 | 1.733 | 1.738 | 1.743 | 1.748 | 1.752 | 68.0 |
| 21 | 1.686 | 1.690 | 1.695 | 1.700 | 1.705 | 1.710 | 1.715 | 1.719 | 1.724 | 1.729 | 1.734 | 1.739 | 1.743 | 69. |
| 22 | 1.677 | 1.682 | 1.686 | 1.691 | 1.696 | 1.701 | 1.706 | 1.710 | 1.715 | 1.720 | 1.725 | 1.730 | 1.734 | 71.6 |
| 23 | 1.668 | 1.673 | 1.677 | 1.682 | 1.687 | 1.692 | 1.696 | 1.701 | 1.706 | 1.711 | 1.716 | 1.720 | 1.725 | 73.4 |
| 24 | 1.659 | 1.664 | 1.668 | 1.673 | 1.678 | 1.683 | 1.687 | 1.692 | 1.697 | 1.702 | 1.706 | 1.711 | 1.716 | 75.2 |
| 25 | 1.650 | 1.654 | 1.659 | 1.664 | 1.669 | 1.673 | 1.678 | 1.683 | 1.688 | 1.692 | 1.697 | 1.702 | 1.706 | 77.0 |
| 26 | 1.640 | 1.645 | 1.650 | 1.654 | 1.659 | 1.664 | 1.669 | 1.673 | 1.678 | 1.683 | 1.687 | 1.692 | 1.697 | 78.8 |
| 27 | 1.631 | 1.636 | 1.640 | 1.645 | 1.650 | 1.654 | 1.659 | 1.664 | 1.669 | 1.673 | 1.678 | 1.683 | 1.687 | 80.6 |
| 28 | 1.621 | 1.626 | 1.631 | 1.635 | 1.640 | 1.645 | 1.649 | 1.654 | 1.659 | 1.664 | 1.668 | 1.673 | 1.677 | 82.4 |
| 29 | 1.612 | 1.616 | 1.621 | 1.626 | 1.630 | 1.635 | 1.640 | 1.644 | 1.649 | 1.654 | 1.658 | 1.663 | 1.668 | 84.2 |
| 30 | 1.602 | 1.607 | 1.611 | 1.616 | 1.620 | 1.625 | 1.630 | 1.634 | 1.639 | 1.644 | 1.648 | 1.653 | 1.658 | 86.0 |
| 31 | 1.592 | 1.597 | 1.601 | 1.606 | 1.610 | 1.615 | 1.620 | 1.624 | 1.629 | 1.634 | 1.638 | 1.643 | 1.648 | 87.8 |
| 32 | 1.582 | 1.587 | 1.591 | 1.596 | 1.600 | 1.605 | 1.610 | 1.614 | 1.619 | 1.624 | 1.628 | 1.633 | 1.638 | 89.6 |
| 33 | 1.572 | 1.577 | 1.581 | 1.586 | 1.590 | 1.595 | 1.599 | 1.603 | 1.608 | 1.613 | 1.618 | 1.623 | 1.627 | 91.4 |
| 34 | 1.562 | 1.566 | 1.571 | 1.576 | 1.580 | 1.585 | 1.589 | 1.593 | 1.598 | 1.603 | 1.607 | 1.612 | 1.617 | 93.2 |
| 35 | 1.551 | 1.556 | 1.561 | 1.565 | 1.569 | 1.575 | 1.579 | 1.583 | 1.588 | 1.592 | 1.597 | 1.602 | 1.606 | 95.0 |
| Inches. . . | 28.34 | 28.42 | 28.50 | 28.58 | 28.66 | 28.74 | 28.82 | 28.90 | 28.98 | 29.06 | 29.13 | 29.21 | 29.29 | . . . . . |

TABLE 2.—*Weight of dry carbon dioxid in milligrams per cubic centimeter of saturated gas.*—*Continued.*

(Corrected for water vapor, etc.—Parr's Table: Jour. Amer. Chem. Soc., 31 : 237.)

| °C. \ mm. | 746 | 748 | 750 | 752 | 754 | 756 | 758 | 760 | 762 | 764 | 766 | 768 | 770 | °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 1.844 | 1.849 | 1.854 | 1.859 | 1.864 | 1.869 | 1.874 | 1.879 | 1.884 | 1.889 | 1.894 | 1.899 | 1.904 | 50.0 |
| 11 | 1.835 | 1.840 | 1.845 | 1.850 | 1.855 | 1.860 | 1.865 | 1.870 | 1.875 | 1.880 | 1.885 | 1.890 | 1.895 | 51.8 |
| 12 | 1.827 | 1.832 | 1.837 | 1.842 | 1.847 | 1.852 | 1.857 | 1.862 | 1.867 | 1.872 | 1.877 | 1.882 | 1.887 | 53.6 |
| 13 | 1.818 | 1.823 | 1.828 | 1.833 | 1.838 | 1.843 | 1.848 | 1.853 | 1.858 | 1.863 | 1.868 | 1.873 | 1.878 | 55.4 |
| 14 | 1.810 | 1.815 | 1.820 | 1.825 | 1.830 | 1.834 | 1.839 | 1.844 | 1.849 | 1.854 | 1.859 | 1.864 | 1.869 | 57.2 |
| 15 | 1.801 | 1.806 | 1.811 | 1.816 | 1.821 | 1.826 | 1.831 | 1.836 | 1.840 | 1.845 | 1.850 | 1.855 | 1.860 | 59.0 |
| 16 | 1.792 | 1.797 | 1.802 | 1.807 | 1.812 | 1.817 | 1.822 | 1.827 | 1.832 | 1.837 | 1.841 | 1.846 | 1.851 | 60.8 |
| 17 | 1.784 | 1.789 | 1.793 | 1.798 | 1.803 | 1.808 | 1.813 | 1.818 | 1.823 | 1.828 | 1.833 | 1.837 | 1.842 | 62.6 |
| 18 | 1.775 | 1.780 | 1.785 | 1.790 | 1.794 | 1.799 | 1.804 | 1.809 | 1.814 | 1.819 | 1.824 | 1.828 | 1.833 | 64.4 |
| 19 | 1.766 | 1.771 | 1.776 | 1.781 | 1.785 | 1.790 | 1.795 | 1.800 | 1.805 | 1.810 | 1.814 | 1.819 | 1.824 | 66.2 |
| 20 | 1.757 | 1.762 | 1.767 | 1.772 | 1.776 | 1.781 | 1.786 | 1.791 | 1.796 | 1.801 | 1.805 | 1.810 | 1.815 | 68.0 |
| 21 | 1.748 | 1.753 | 1.758 | 1.763 | 1.767 | 1.772 | 1.777 | 1.782 | 1.787 | 1.791 | 1.796 | 1.801 | 1.806 | 69.8 |
| 22 | 1.739 | 1.744 | 1.749 | 1.753 | 1.758 | 1.763 | 1.768 | 1.773 | 1.777 | 1.782 | 1.787 | 1.792 | 1.797 | 71.6 |
| 23 | 1.730 | 1.735 | 1.739 | 1.744 | 1.749 | 1.754 | 1.759 | 1.763 | 1.768 | 1.773 | 1.778 | 1.782 | 1.787 | 73.4 |
| 24 | 1.721 | 1.725 | 1.730 | 1.735 | 1.740 | 1.744 | 1.749 | 1.754 | 1.759 | 1.763 | 1.768 | 1.773 | 1.778 | 75.2 |
| 25 | 1.711 | 1.716 | 1.721 | 1.725 | 1.730 | 1.735 | 1.740 | 1.744 | 1.749 | 1.754 | 1.759 | 1.763 | 1.768 | 77.0 |
| 26 | 1.702 | 1.706 | 1.711 | 1.716 | 1.721 | 1.725 | 1.730 | 1.735 | 1.739 | 1.744 | 1.749 | 1.754 | 1.758 | 78.8 |
| 27 | 1.692 | 1.697 | 1.701 | 1.706 | 1.711 | 1.716 | 1.720 | 1.725 | 1.730 | 1.734 | 1.739 | 1.744 | 1.748 | 80.6 |
| 28 | 1.682 | 1.687 | 1.692 | 1.696 | 1.701 | 1.706 | 1.710 | 1.715 | 1.720 | 1.724 | 1.729 | 1.734 | 1.739 | 82.4 |
| 29 | 1.672 | 1.677 | 1.682 | 1.686 | 1.691 | 1.696 | 1.700 | 1.705 | 1.710 | 1.714 | 1.719 | 1.724 | 1.728 | 84.2 |
| 30 | 1.662 | 1.667 | 1.672 | 1.676 | 1.681 | 1.686 | 1.690 | 1.695 | 1.700 | 1.704 | 1.709 | 1.714 | 1.718 | 86.0 |
| 31 | 1.652 | 1.657 | 1.662 | 1.666 | 1.670 | 1.675 | 1.680 | 1.685 | 1.689 | 1.694 | 1.699 | 1.703 | 1.708 | 87.8 |
| 32 | 1.642 | 1.646 | 1.651 | 1.656 | 1.660 | 1.664 | 1.669 | 1.674 | 1.679 | 1.683 | 1.688 | 1.693 | 1.697 | 89.6 |
| 33 | 1.631 | 1.636 | 1.641 | 1.645 | 1.649 | 1.654 | 1.659 | 1.664 | 1.668 | 1.673 | 1.677 | 1.682 | 1.687 | 91.4 |
| 34 | 1.620 | 1.625 | 1.630 | 1.635 | 1.639 | 1.643 | 1.648 | 1.653 | 1.658 | 1.662 | 1.666 | 1.671 | 1.676 | 93.2 |
| 35 | 1.610 | 1.615 | 1.620 | 1.624 | 1.629 | 1.633 | 1.638 | 1.643 | 1.647 | 1.651 | 1.656 | 1.660 | 1.665 | 95.0 |
| Inches... | 29.37 | 29.45 | 29.53 | 29.61 | 29.68 | 29.76 | 29.84 | 29.92 | 30.00 | 30.08 | 30.16 | 30.24 | 30.31 | ..... |

TABLE 3.—*Weight of dry air in milligrams per cubic centimeter of saturated atmosphere at various temperatures and at various barometric pressures.*

| °C. \ mm. | 720 | 722 | 724 | 726 | 728 | 730 | 732 | 734 | 736 | 738 | 740 | 742 | 744 | °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 1.168 | 1.171 | 1.174 | 1.177 | 1.180 | 1.184 | 1.187 | 1.190 | 1.193 | 1.197 | 1.200 | 1.203 | 1.206 | 50.0 |
| 11 | 1.162 | 1.166 | 1.169 | 1.172 | 1.175 | 1.179 | 1.182 | 1.185 | 1.188 | 1.191 | 1.195 | 1.198 | 1.201 | 51.8 |
| 12 | 1.157 | 1.160 | 1.164 | 1.167 | 1.170 | 1.173 | 1.177 | 1.180 | 1.183 | 1.186 | 1.189 | 1.193 | 1.196 | 53.6 |
| 13 | 1.152 | 1.155 | 1.159 | 1.162 | 1.165 | 1.168 | 1.171 | 1.175 | 1.178 | 1.181 | 1.184 | 1.187 | 1.190 | 55.4 |
| 14 | 1.147 | 1.150 | 1.153 | 1.157 | 1.160 | 1.163 | 1.166 | 1.169 | 1.172 | 1.176 | 1.179 | 1.182 | 1.185 | 57.2 |
| 15 | 1.142 | 1.145 | 1.148 | 1.151 | 1.154 | 1.158 | 1.161 | 1.164 | 1.167 | 1.170 | 1.173 | 1.177 | 1.180 | 59.0 |
| 16 | 1.137 | 1.140 | 1.143 | 1.146 | 1.149 | 1.152 | 1.156 | 1.159 | 1.162 | 1.165 | 1.168 | 1.171 | 1.174 | 60.8 |
| 17 | 1.131 | 1.134 | 1.138 | 1.141 | 1.144 | 1.147 | 1.150 | 1.153 | 1.156 | 1.160 | 1.163 | 1.166 | 1.169 | 62.6 |
| 18 | 1.126 | 1.129 | 1.132 | 1.135 | 1.138 | 1.141 | 1.145 | 1.148 | 1.151 | 1.154 | 1.157 | 1.160 | 1.163 | 64.4 |
| 19 | 1.121 | 1.124 | 1.127 | 1.130 | 1.133 | 1.136 | 1.139 | 1.142 | 1.146 | 1.149 | 1.152 | 1.155 | 1.158 | 66.2 |
| 20 | 1.115 | 1.118 | 1.121 | 1.124 | 1.128 | 1.131 | 1.134 | 1.137 | 1.140 | 1.143 | 1.146 | 1.149 | 1.152 | 68.0 |
| 21 | 1.110 | 1.113 | 1.116 | 1.119 | 1.122 | 1.125 | 1.128 | 1.131 | 1.134 | 1.138 | 1.141 | 1.144 | 1.147 | 69.8 |
| 22 | 1.104 | 1.107 | 1.110 | 1.113 | 1.117 | 1.120 | 1.123 | 1.126 | 1.129 | 1.132 | 1.135 | 1.138 | 1.141 | 71.6 |
| 23 | 1.099 | 1.102 | 1.105 | 1.108 | 1.111 | 1.114 | 1.117 | 1.120 | 1.123 | 1.126 | 1.129 | 1.132 | 1.135 | 73.4 |
| 24 | 1.093 | 1.096 | 1.099 | 1.102 | 1.105 | 1.108 | 1.111 | 1.114 | 1.117 | 1.120 | 1.123 | 1.126 | 1.130 | 75.2 |
| 25 | 1.087 | 1.090 | 1.093 | 1.096 | 1.099 | 1.102 | 1.106 | 1.109 | 1.112 | 1.115 | 1.118 | 1.121 | 1.124 | 77.0 |
| 26 | 1.082 | 1.085 | 1.088 | 1.091 | 1.094 | 1.097 | 1.100 | 1.103 | 1.106 | 1.109 | 1.112 | 1.115 | 1.118 | 78.8 |
| 27 | 1.076 | 1.079 | 1.082 | 1.085 | 1.088 | 1.091 | 1.094 | 1.097 | 1.100 | 1.103 | 1.106 | 1.109 | 1.112 | 80.6 |
| 28 | 1.070 | 1.073 | 1.076 | 1.079 | 1.082 | 1.085 | 1.088 | 1.091 | 1.094 | 1.097 | 1.100 | 1.103 | 1.106 | 82.4 |
| 29 | 1.064 | 1.067 | 1.070 | 1.073 | 1.077 | 1.079 | 1.082 | 1.085 | 1.088 | 1.090 | 1.093 | 1.096 | 1.099 | 84.2 |
| 30 | 1.058 | 1.061 | 1.064 | 1.067 | 1.070 | 1.073 | 1.075 | 1.078 | 1.081 | 1.084 | 1.087 | 1.090 | 1.093 | 86.0 |
| 31 | 1.052 | 1.055 | 1.058 | 1.060 | 1.063 | 1.066 | 1.069 | 1.072 | 1.075 | 1.078 | 1.081 | 1.084 | 1.087 | 87.8 |
| 32 | 1.045 | 1.048 | 1.051 | 1.054 | 1.057 | 1.060 | 1.063 | 1.066 | 1.069 | 1.071 | 1.074 | 1.077 | 1.080 | 89.6 |
| 33 | 1.039 | 1.042 | 1.045 | 1.048 | 1.051 | 1.053 | 1.056 | 1.059 | 1.062 | 1.065 | 1.068 | 1.071 | 1.074 | 91.4 |
| 34 | 1.032 | 1.035 | 1.038 | 1.041 | 1.044 | 1.047 | 1.050 | 1.053 | 1.055 | 1.058 | 1.061 | 1.064 | 1.067 | 93.2 |
| 35 | 1.026 | 1.029 | 1.032 | 1.034 | 1.037 | 1.040 | 1.043 | 1.046 | 1.049 | 1.052 | 1.054 | 1.057 | 1.060 | 95.0 |
| Inches... | 28.34 | 28.42 | 28.50 | 28.58 | 28.66 | 28.74 | 28.82 | 28.90 | 28.98 | 29.06 | 29.13 | 29.21 | 29.29 | ..... |

TABLE 3.—*Weight of dry air in milligrams per cubic centimeter of saturated atmosphere.*—**Continued.**

| mm. / °C. | 746 | 748 | 750 | 752 | 754 | 756 | 758 | 760 | 762 | 764 | 766 | 768 | 770 | °F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 1.210 | 1.213 | 1.216 | 1.219 | 1.223 | 1.226 | 1.229 | 1.232 | 1.236 | 1.239 | 1.242 | 1.245 | 1.249 | 50.0 |
| 11 | 1.204 | 1.208 | 1.211 | 1.214 | 1.217 | 1.220 | 1.224 | 1.227 | 1.230 | 1.233 | 1.237 | 1.240 | 1.243 | 51.8 |
| 12 | 1.199 | 1.202 | 1.206 | 1.209 | 1.212 | 1.215 | 1.218 | 1.222 | 1.225 | 1.228 | 1.231 | 1.234 | 1.238 | 53.6 |
| 13 | 1.194 | 1.197 | 1.200 | 1.203 | 1.207 | 1.210 | 1.213 | 1.216 | 1.219 | 1.223 | 1.226 | 1.229 | 1.232 | 55.4 |
| 14 | 1.188 | 1.192 | 1.195 | 1.198 | 1.201 | 1.204 | 1.208 | 1.211 | 1.214 | 1.217 | 1.220 | 1.223 | 1.227 | 57.2 |
| 15 | 1.183 | 1.186 | 1.189 | 1.193 | 1.196 | 1.199 | 1.202 | 1.205 | 1.208 | 1.211 | 1.215 | 1.218 | 1.221 | 59.0 |
| 16 | 1.178 | 1.181 | 1.184 | 1.187 | 1.190 | 1.193 | 1.197 | 1.200 | 1.203 | 1.206 | 1.209 | 1.212 | 1.215 | 60.8 |
| 17 | 1.172 | 1.175 | 1.178 | 1.181 | 1.185 | 1.188 | 1.191 | 1.194 | 1.197 | 1.200 | 1.203 | 1.207 | 1.210 | 62.6 |
| 18 | 1.167 | 1.170 | 1.173 | 1.176 | 1.179 | 1.182 | 1.185 | 1.189 | 1.192 | 1.195 | 1.198 | 1.201 | 1.204 | 64.4 |
| 19 | 1.161 | 1.164 | 1.167 | 1.170 | 1.173 | 1.177 | 1.180 | 1.183 | 1.186 | 1.189 | 1.192 | 1.195 | 1.198 | 66.2 |
| 20 | 1.156 | 1.159 | 1.162 | 1.165 | 1.168 | 1.171 | 1.174 | 1.177 | 1.180 | 1.183 | 1.186 | 1.190 | 1.193 | 68.0 |
| 21 | 1.150 | 1.153 | 1.156 | 1.159 | 1.162 | 1.165 | 1.168 | 1.171 | 1.175 | 1.178 | 1.181 | 1.184 | 1.187 | 69.8 |
| 22 | 1.144 | 1.147 | 1.150 | 1.153 | 1.156 | 1.159 | 1.162 | 1.166 | 1.169 | 1.172 | 1.175 | 1.178 | 1.181 | 71.6 |
| 23 | 1.138 | 1.141 | 1.144 | 1.148 | 1.151 | 1.154 | 1.157 | 1.160 | 1.163 | 1.166 | 1.169 | 1.172 | 1.175 | 73.4 |
| 24 | 1.133 | 1.136 | 1.139 | 1.142 | 1.145 | 1.148 | 1.151 | 1.154 | 1.157 | 1.160 | 1.163 | 1.166 | 1.169 | 75.2 |
| 25 | 1.127 | 1.130 | 1.133 | 1.136 | 1.139 | 1.142 | 1.145 | 1.148 | 1.151 | 1.154 | 1.157 | 1.160 | 1.163 | 77.0 |
| 26 | 1.121 | 1.124 | 1.127 | 1.130 | 1.133 | 1.136 | 1.139 | 1.142 | 1.145 | 1.148 | 1.151 | 1.154 | 1.157 | 78.8 |
| 27 | 1.115 | 1.118 | 1.121 | 1.124 | 1.127 | 1.130 | 1.133 | 1.136 | 1.139 | 1.142 | 1.145 | 1.148 | 1.151 | 80.6 |
| 28 | 1.108 | 1.111 | 1.114 | 1.117 | 1.120 | 1.123 | 1.126 | 1.129 | 1.132 | 1.135 | 1.138 | 1.141 | 1.144 | 82.4 |
| 29 | 1.102 | 1.105 | 1.108 | 1.111 | 1.114 | 1.117 | 1.120 | 1.123 | 1.126 | 1.129 | 1.132 | 1.135 | 1.138 | 84.2 |
| 30 | 1.096 | 1.099 | 1.102 | 1.105 | 1.108 | 1.111 | 1.114 | 1.117 | 1.120 | 1.122 | 1.125 | 1.128 | 1.131 | 86.0 |
| 31 | 1.090 | 1.093 | 1.095 | 1.098 | 1.101 | 1.104 | 1.107 | 1.110 | 1.113 | 1.116 | 1.119 | 1.122 | 1.125 | 87.8 |
| 32 | 1.083 | 1.086 | 1.089 | 1.092 | 1.095 | 1.098 | 1.100 | 1.103 | 1.106 | 1.109 | 1.112 | 1.115 | 1.118 | 89.6 |
| 33 | 1.076 | 1.079 | 1.082 | 1.085 | 1.088 | 1.091 | 1.094 | 1.097 | 1.100 | 1.102 | 1.105 | 1.108 | 1.111 | 91.4 |
| 34 | 1.070 | 1.073 | 1.076 | 1.078 | 1.081 | 1.084 | 1.087 | 1.090 | 1.093 | 1.096 | 1.098 | 1.101 | 1.104 | 93.2 |
| 35 | 1.063 | 1.066 | 1.069 | 1.072 | 1.074 | 1.077 | 1.080 | 1.083 | 1.086 | 1.089 | 1.091 | 1.094 | 1.097 | 95.0 |
| Inches... | 29.37 | 29.45 | 29.53 | 29.61 | 29.68 | 29.76 | 29.84 | 29.92 | 30.00 | 30.08 | 30.16 | 30.24 | 30.31 | ...... |

# AGRONOMIC AFFAIRS.

## NEW BOOKS.

*Productive Farm Crops.* By E. G. MONTGOMERY, Professor of Farm Crops, New York State College of Agriculture, Cornell University. J. B. Lippincott Co. (Philadelphia and London), 1916. 21½ cm. Pages 501 + xix; figs, 203; col. frontispiece.

There has been a great need for a comprehensive textbook in one volume covering the entire subject of economic farm crops. The demand comes largely from secondary agricultural schools and from short-course students in agricultural colleges. Students of college grade are perhaps better taught by the lecture method. Such a book should be complete so that the student who is educated in agriculture may know something of the crops grown outside the region where he lives. It should be written in a language which may be understood by student who is without technical training, but must not be so simple as to be uninteresting.

The space allotted to each crop should bear some proportion to the importance of that crop to the whole production. It should be so arranged with appropriate headings and subheadings that it is teachable. "Productive Farm Crops" seems to meet all of these requirements in a satisfactory manner. Many other good books have been written which cover the same subject. In fact, practically all of the information contained in "Productive Farm Crops" may be found in other well-known works, but these other books usually are written for some particular region, are limited to a certain crop or group of crops, or else they contain a mass of irrelevant matter as soil physics, orchard management, and stock judging.

Professor Montgomery has produced a first-class text book. Where but one volume is desired it would be valuable also as a reference book. For reference purposes, however, a collection of two or more of the leading agricultural books, as one on the grains, another on forage crops, and perhaps another on fiber crops, would be more serviceable.

It is customary in reviewing a book to find some fault with it. In this case it may be suggested that sugar-cane growing is of enough importance in this country to merit discussion; that sugar beets should be treated apart from mangels; and that hemp, hops, chufas, cassava each deserve a short paragraph. Sunflowers and artichokes might also be mentioned. These omissions are not serious and sink

into insignificance when compared with the merit which the book possesses.—Lyman Carrier.

## MEMBERSHIP CHANGES.

The membership reported in the previous issue was 609. Since that time 2 members have resigned and 11 new members have been added, making a net gain of 9 and a total membership at this time of 618. The names and addresses of the new members, the names of the members resigned, and such changes of address as have come to the notice of the Secretary are printed below.

### New Members.

Clark, Geo. H., Seed Commissioner, Dept. Agr., Ottawa, Canada.
Criswell, Judson H., 2807 Quarry Road, Washington, D. C.
Finnell, H. Howard, 203 Boys' Dormitory, College of Agr., Stillwater, Okla.
Hodson, Edgar A., 207 Delaware Ave., Ithaca, N. Y.
Holland, B. B., Box No. 46, Route 1, Memphis, Texas.
Kennedy, P. B., 11 Budd Hall, College of Agr., Berkeley, Cal.
Lippitt, W. D., Great Western Sugar Co., 500 Sugar Bldg., Denver, Colo.
Miller, Frank R., Bowker Fert. Co., 43 Chatham St., Boston, Mass.
Mathews, Oscar R., Belle Fourche Expt. Farm, Newell, S. Dak.
Ratliffe, George T., Belle Fourche Expt. Farm, Newell, S. Dak.
Winters, N. E., Supt., Substation No. 3, Angleton, Texas.

### Members Resigned.

Laidlaw, C. M., Physics Dept., Ontario Agr. College, Guelph, Ontario.
Stoddart, Chas. W., Dept. Chem., Pa. State College, State College, Pa.

### Addresses Changed.

Atwater, C. G., Agr. Dept., The Barrett Co., 17 Battery Place, New York, N. Y.
Bliss, S. W., 17 Fifteenth Ave., Columbus, Ohio.
du Buisson, J. P., Senekal, OFSP., South Africa.
Kemp, W. B., Maryland State College, College Park, Md.
McLane, J. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Tucker, Geo. M., R. F. D. No. 8, Chevy Chase, Md.
Schmitz, Nickolas, Pennsylvania State College, State College, Pa.

## NOTES AND NEWS.

Victor L. Cory, superintendent of the Denton (Texas) substation at Krum, Texas, has resigned and on March 1 sailed for Freetown, Sierre Leone.

James W. Day has been appointed assistant in agronomy and Joseph R. Neller, research assistant in soils, at the New Jersey station.

R. J. H. De Loach, for the past several years director of the Georgia station, has resigned and is now in charge of the service bureau of the Armour Fertilizer Co., with headquarters at Chicago.

C. A. Dorchester, assistant in farm crops, and J. A. Krall, of the farm crops extension force, have exchanged positions in the Iowa college for the college year 1916–17.

A. R. Evans, instructor in farm crops in the University of Missouri, has resigned to accept a position in the Office of Markets of the U. S. Department of Agriculture.

Edward T. Fairchild, president of the New Hampshire college since 1912, died at Durham, N. H., on January 23.

J. N. Harper, director of the South Carolina station since 1905, has resigned to take charge of the service bureau of the Southern Fertilizer Association, with headquarters at Atlanta. J. C. Pridmore, associate professor of agronomy at the University of Tennessee, resigned on February 1 to become associated with him in this work.

Arthur Huisken is now an assistant in soils at the Ohio station.

Ove F. Jensen, who was engaged in graduate study at Iowa State College last year, since July 1 has been assistant in crop production at that institution.

Clarence C. Logan, assistant in soil extension, Ward H. Sachs, associate in chemistry, and F. C. Richey, assistant in soil physics, all of the Illinois station, have resigned.

M. L. Nichols has been appointed assistant professor of agronomy and assistant agronomist in the Delaware college and station.

M. E. Olson, formerly farm crops superintendent at the Iowa station, on September 1 resigned to enter the Office of Corn Investigations, U. S. Department of Agriculture.

A. M. Peter is acting director of the Kentucky station, not director, as reported in the January JOURNAL.

D. W. Pittman is now instructor in agronomy and assistant agronomist in the Utah college and station.

George Roberts, treasurer of the American Society of Agronomy and head of the department of agronomy of the Kentucky College of Agriculture, has been appointed acting dean of that college, *vice* J. H. Kastle, deceased.

W. H. McIntire, assistant in soil chemistry at the Tennessee station, has recently returned from leave of absence for graduate study at Cornell University, where he was granted the degree of Ph.D.

G. L. Schuster became assistant in farm crops and R. G. Wiggans assistant professor of farm crops at Ohio State University with the beginning of the college year.

John B. Smith has been appointed assistant in crops at the Missouri station.

T. H. Stafford has succeeded H. L. Joslyn as assistant professor of soils at the North Carolina college.

A. M. Ten Eyck, agricultural agent in Winnebago County, Ill., since 1914 and previous to that time extensions professor of soils at the Iowa college and professor of agronomy at the Kansas college, is now in charge of the agricultural service bureau of the Emerson-Brantingham Company, manufacturers of agricultural implements, with headquarters at Rockford, Ill.

R. S. Thomas as assistant in soils and W. R. M. Scott as assistant in farm crops are recent appointments at Purdue University.

At the annual meeting of the American Association for the Advancement of Science, held in New York, December 26–30, the address of Dean Eugene Davenport, the retiring vice-president of Section M, agriculture, was entitled "The Outlook for Agriculture." The topic discussed at the meeting of this section was "The Adjustment of Science to Practice in Agriculture." Different phases of this topic were discussed by Dr. H. J. Wheeler, of Boston, Dr. G. F. Warren, of Cornell University, Director J. G. Lipman, of the New Jersey station, and Director B. Youngblood, of the Texas station.

The International Dry-Farming Congress, the National Irrigation Congress, and the International Soil-Products Exposition were held at El Paso, Texas, October 19–26, 1916. President W. M. Jardine,

of the Dry-Farming Congress, outlined the history of the congress, told of the progress of the dry-farming movement, and stated that the work of the future must include the encouragement of livestock production, the betterment of home conditions, and the provision of profitable work for the farmer and his family throughout the year. Other speakers were Director Youngblood and A. H. Leidigh of the Texas station, President E. G. Peterson of the Utah Agricultural College, Director Forbes of the Arizona station, Professor Throckmorton of the Kansas college, Col. A. J. Bester of South Africa, Niel Nielson of Australia, and J. M. Romagny of France. Gov. Frank M. Byrne of South Dakota was elected president for 1917.

## Meeting of Southern Agronomists.

The eighteenth annual convention of the Association of Southern Agricultural Workers was held in New Orleans, La., January 24–26, 1917. The officers of the association for the past year were W. M. Riggs (S. C.), *president;* T. D. Boyd (La.), *vice-president;* and Dan T. Gray (N. C.), *secretary.* General sessions were held in the mornings, while the afternoons were devoted to special sessions of the livestock and agronomy sections. H. A. Morgan (Tenn.), was chairman of the agronomy section, and T. E. Keitt (S. C.), secretary.

Perhaps the most important feature of the meeting from an agronomic standpoint was the report of the committee on coordinating investigational work in agronomy in the South. This committee consisted of C. B. Williams (N. C.), *chairman,* and C. A. Mooers (Tenn.), A. F. Kidder (La.), C. K. McClelland (Ga.), and T. E. Keitt (S. C.). After presenting a list of projects in agronomy now under way at the Southern stations and showing wherein there was an overlapping in these projects, the committee made certain recommendations which may be briefly outlined as follows:

1. That eight main soil provinces be recognized and that these provinces be used as a basis in adjusting agronomic experimentation among the States.

2. That new work be planned to eliminate duplication, particularly on soils of the same character.

3. That work now in force be adjusted so as to correlate and eliminate duplication.

4. That certain important fundamental data be reported in connection with each experiment.

5. That the States Relations Service be requested to designate a man to collect and classify the projects in agronomy at the Southern stations and to advise the station directors regarding work being done at other stations in the South.

6. That duplication of work in plant production be confined, so far as possible, to duplication on different soil types or under different climatic conditions.

7. That in varietal tests the source of seed be given and be uniform, if possible.

8. That varietal tests be conducted mainly to determine the best strains for local conditions and that improvement work be started with these best strains after they are determined.

9. That the agronomic work at the stations be in charge of men trained and educated along agronomic lines.

## Local Sections.

At the fall meetings of the Iowa section, the progress of experimental work in agronomy in various States has been discussed. Officers of this section elected in October are: Clyde McKee, *president;* H. W. Warner, *vice-president;* Ove F. Jensen, *secretary;* and R. H. Bancroft, *treasurer.*

The North Carolina local section of the American Society of Agronomy was organized at West Raleigh on December 19, 1916. The following officers were elected: C. B. Williams, *president;* C. L. Newman, *vice-president;* and W. F. Pate, *secretary-treasurer.* It is probable that the section will have about 20 members when organization is completed.

The thirteenth regular meeting of the Washington (D. C.) section was held at the Cosmos Club, December 18, 1916. The annual report of the secretary-treasurer was presented, after which the following officers were elected for the ensuing year: C. E. Leighty, *president;* John S. Cole, *vice-president;* A. C. Dillman, *secretary-treasurer;* and P. V. Cardon and Chas. E. Chambliss, *additional members of the executive committee.* Mr. C. H. Clark then presented an illustrated paper on "Experiments with Seed Flax as a Winter Crop for the Southwest," in which it was pointed out that a large part of the world's flax crop was produced from fall seeding and that preliminary experiments in our own Southwest indicated the possibility of the establishment of an important new center of flaxseed production there. Mr. Frank C. Miles followed with an illustrated paper entitled "Production of Hemp and Flax Fiber in the United States." Mr. Miles gave statistics of the production of these two fiber crops, showed where and how they are produced, and outlined and illustrated the methods by which the fiber is separated from the woody portions of the stalks.

The fourteenth regular meeting of the Washington (D. C.) section was held at the Cosmos Club on January 17, 1917, at 8 p.m. The general subject for the evening, "Field Stations of the Bureau of Plant Industry," was discussed by several speakers, with illustrations. "The History and Development of Field Stations" was outlined by Dr. B. T. Galloway, after which the work of the field stations of the various offices was discussed by the following: plant introduction gardens, P. H. Dorsett; dry-land stations, John S. Cole; irrigation stations, C. S. Scofield; forage-crop stations, H. N. Vinall; and cereal stations, H. V. Harlan and Chas. E. Chambliss. The program was followed by a social hour, with refreshments.

## DIRECTORY OF LOCAL SECTIONS.

### Georgia State College.

President,
Secretary, Geo. A. Crabb.

### Cornell University.

President, B. D. Wilson.

### Iowa State College.

President, Clyde McKee.
Secretary, Ove F. Jenson.

### Kansas State Agricultural College.

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Secretary,

### South Dakota State College.

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### New England.

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Secretary, Earl Jones, Amherst, Mass.

### Washington, D. C.

President, C. E. Leighty.
Secretary, A. C. Dillman.

# JOURNAL

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## LIVESTOCK AND THE MAINTENANCE OF ORGANIC MATTER IN THE SOIL.[1]

ELMER O. FIPPIN.

Organic matter in the soil is universally recognized as necessary to its largest productiveness. Maintenance of the organic matter constitutes one of the most trying problems of practical farming. In this paper it is desired, first, to press the importance of the organic constituents perhaps a little further than has commonly been done; and second, to direct attention to the effect of animals on the organic matter in the feed consumed in a way that has not been emphasized in the ordinary discussion of soil maintenance and livestock husbandry.

### PHYSICAL AND NUTRIENT FUNCTIONS OF ORGANIC MATTER.

All of us readily concede the important physical effects of organic matter in its partially decayed form, in respect to structure and tilth, moisture capacity, color, and heat absorption. We also emphasize its importance as a source of moderately available plant nutrients and the preeminent storehouse of combined soil nitrogen. It is our custom to say that the plant substance is broken down in the process of decay and the nutrients reduced to very simple and soluble forms, such as nitric acid and the ions of the bases. These may be taken up by the roots of the growing plant and used in building new structures.

It is not long since the use of nitrogen was limited to the nitrate form. The destruction of the highly organized nitrogenous sub-

[1] Presented at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1916.

stances of organic material, the liberation of ammonia, and its oxidation to nitrates by the various steps involving the intervention of microorganisms has been explained as the limiting factor in the availability of organic carriers of nitrogen.

Without minimizing the operation of those processes, it is now known that many plants use ammonia and the amino radical as a source of nitrogen. Some plants (e. g., rice)[2] seem to prefer the ammonia form of nitrogen to the nitrate form. An experienced English florist and gardener at Auburn, N. Y., states that it is possible to force flowers and fruits in the greenhouse by exposing vats of liquid manure and other materials that will charge the atmosphere with ammonia. Not only the use of ammonia but its possible assumption through the aerial structures suggest interesting studies. It is also interesting to speculate—since very few data are available—on the possible correlation between the natural habitat of a plant (for example, rice in a marsh) and the kind of nitrogen fertilizer to which it will respond.

### Organic Forms of Nitrogen as Plant Food.

The stir that has pervaded soil-fertility circles for the last twelve years has brought forward the idea of the toxicity to plants of certain organic soil constituents[3] that all openminded students of the subject of fertility are bound to accept as a factor in the system. This activity has also been coincident with and in part has led to the establishment of the first important fact that is here emphasized, namely, that plants can use nitrogen in highly organized compounds, such as creatinine,[4] casein, and barbituric acid.[5]

This fact in itself is of large significance and should rearrange much of our teaching concerning practical soil management. It should give a new angle of vision on the use of stock and green manures. It should stimulate a close examination of the nitrogenous

[2] Kelley, W. P. The assimilation of nitrogen by rice. Hawaii Agr. Expt. Sta. Bul. 24. 1911.

[3] Schreiner, Oswald, Reed, H. S., and Skinner, J. J. Certain organic constituents of soils in relation to soil fertility. U. S. Dept. Agr., Bur. Soils Bul. 47. 1907. Further data on the subject are contained in later bulletins by Dr. Schreiner and his associates.

[4] Schreiner, Oswald, Shorey, Edmund C., Sullivan, M. X., and Skinner, J. J. A beneficial organic constituent of soils: creatinine. U. S. Dept. Agr., Bur. Soils Bul. 83. 1911.

[5] Hutchinson, H. B., and Miller, N. H. J. The direct assimilation of inorganic and organic forms of nitrogen by higher plants. *In* Centbl. Bakt., 2: 513–547. 1911.

compounds in plants and in animal wastes with reference to their direct use by plants. It suggests a further reason for study of the micro and the macro plant organisms in the soil, viz., their effect on the form and solubility of the organic nitrogenous substances. This is, of course, going on in commendable fashion in several laboratories.

### Higher Plants Use Organized Carbonaceous Material.

The second point to be emphasized is that the soil organic matter may contribute organized non-nitrogenous materials directly to the growing plant. It is now quite definitely established that plants can use many kinds of highly organized carbonaceous compounds provided they are soluble, which solubility is of course essential to their transfer. The growing plant is able to use, to build into its new structure, ready-made molecules produced in an antecedent organism. It is like constructing a house of made-up parts, building up a book-case of sections.

Knudson,[6] of the Cornell Station, has reviewed the available literature on this point and reports a considerable amount of investigation, showing that the common range of plants, such as corn, timothy, field peas, radishes, and hairy vetch can utilize such a wide range of materials as sugars, alcohols, aldehydes, and organic acids. The substances used in his investigation were saccharose, maltose, lactose, glucose, and galactose. With the possible exception of galactose, all these substances caused a marked increase in growth under sterile conditions. Hutchinson and Miller[7] report relative to the assimilation of nitrogen compounds that "more or less satisfactory evidence of assimilation has been obtained," with a list of eighteen nitrogenous organic substances mentioned.

### Organic Matter a Source of Energy to Plants.

An additional point in connection with the use of these organized materials is the energy relations of the system. Every organic molecule such as those mentioned represents the storage of a definite amount of energy. That energy is derived from light, commonly sunshine. If it is possible for a plant to use material elaborated by the light falling upon the leaves of a preceding plant, the new plant, using its own leaves to the full to receive the sunshine, should make a larger growth in a given time.

[6] Knudson, L. Influence of certain carbohydrates on green plants. N. Y. (Cornell) Agr. Expt. Sta. Memoir 9. 1916.

[7] Hutchinson, H. B., and Miller, N. H. J. *Loc. cit.*

Knudson, in the paper previously mentioned, found that plants were able to make a measurable increase in dry matter under sterile conditions in the dark, thus indicating the direct use by the growing cells of the sugars studied. It is commonly recognized that the saprophytic organisms are dependent on this form of energy and that this relation intimately controls such important processes as the fixation of nitrogen. That higher plants are also able to use such material is a most significant discovery.

The practical aspect of this matter is the common custom of expert plant growers to load up their soil with freshly decayed organic matter. We never obtain the largest plant growth in a mineral soil, however large the supply of simple nutrients may be. The applications of manure in greenhouse and gardening practice bears no direct relation to the total soluble nitrogen and other nutrients supplied. The results suggest the sorting out and use of the suitable organized material that may represent only part of the soluble nutrients, not to mention the simple forms used under the influence of sunshine.

I suggest the desirability of studying plant growth from the point of view of energy relations and the possibility of connection between this matter and the thermal sum for crop maturity.[8]

## Effect of Animals on Organic Matter in Feed.

We now come to consider the relation of livestock through their manure to the maintenance of soil organic matter. It is evident that if organic matter is important because of its organized structure and energy relations, as well as for its physical effects and supply of nutrients, a careful inquiry must be made into the effects of the animal on those organic materials. It has been customary to put the emphasis on the nitrogen, phosphorus, and potassium in the material, and by inference to suggest that the recovery of organic matter from the feed is similar in proportion to that of the nutrients. When the organic matter is considered, I suspect the average person is misled by the bulk of the material, made large by added water.

## Digestibility of Feeds.

The newer method of rating the feeding value of materials in terms of energy units provides data from which this matter may be studied. Armsby and his associates have made determinations in the calorimeter at State College, Pa., of the distribution of the energy

[8] Bolls, W. L. Temperature and growth. *In* Annals of Botany, 22: 557–592. 1908.

units in the feed consumed to the various body processes, and in the waste in both the undigested and the digested material.[9] These determinations cover a number of standard feeds and the use of several animals. Our interest in the results is the converse of the feeder's. We are concerned with the wasted residue. The energy or thermal value of the material very well suits our purposes of estimating the

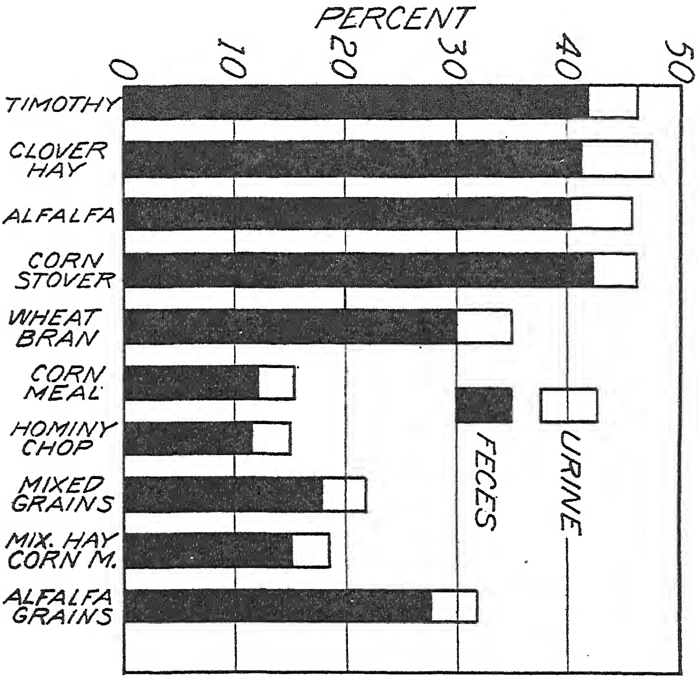


FIG. 5. Graph showing minimum percentages of organic matter recovered in animal feces and urine, with the sums of the minima.

organic matter available after an animal has consumed and digested its feed. Table I and figure 5 show the proportion of organic matter in the solid and liquid feces.

There is an additional waste of energy in the bowel gases, mostly methane, amounting to 6 to 11 percent of the energy of the feed. Of this no account is taken, as it is assumed to be lost.

From this table it is apparent that the animal returns only from a seventh to less than a half of the organic matter in the feed. The return is largest for the coarse, fibrous materials and lowest for the

[9] Armsby, H. P., and Fries, J. A. Net energy values of feeding stuffs for cattle. *In* U. S. Dept. Agr., Jour. Agr. Research, 3: 435–491. 1915.

concentrates. The former are usually grown at home, the latter are largely purchased. This point bears on the importance of purchased feed in maintaining the soil.

TABLE 1.—*Maximum and minimum percentages of organic matter in various feeds recovered in animal feces and urine, with the sums of the minima.*

| Feed. | Percentage recovered. | | Sum of minima. |
|---|---|---|---|
| | In feces. | In urine. | |
| Timothy | 41.6–49.5 | 3.9–4.6 | 45.5 |
| Clover hay | 41.0–42.7 | 6.7–6.8 | 47.7 |
| Alfalfa hay | 40.0–47.0 | 5.5–6.4 | 45.5 |
| Corn stover | 42.0–43.0 | 4.0–4.5 | 46.0 |
| Wheat bran | 30.0–33.0 | 5.0–6.9 | 35.0 |
| Corn meal | 12.0–15.0 | 3.3–7.0 | 15.3 |
| Hominy chop | 11.5–13.0 | 3.6–4.2 | 15.1 |
| Mixed grain No. 2 | 18.0–27.3 | 3.7–5.2 | 21.7 |
| Mixed hay and corn meal | 20.0–28.0 | 3.5–4.2 | 23.5 |
| Alfalfa hay and grain | 27.5–34.0 | 4.3–5.3 | 31.8 |

## PRODUCTION OF MANURE.

Comparison may be made of the digestion figures with the recovery of organic matter in feeding practice. While there are many data on the production of manure, very few of the investigations have carried out all the weighings and determinations necessary to a conclusion.

At Cornell University, R. E. Deuel investigated the production of manure and its several constituents by the college herd of 46 cows, The measurements covered a period of seven days and were the basis of a thesis for an advanced degree. The cows averaged 1,008 pounds in weight and were fed a ration that averaged 8.8 pounds of grain, 30 pounds of silage, 10.2 pounds of low-grade alfalfa hay, and 4.2 pounds of mangels. The grain consisted of cornmeal, distillers' grain, and bran, with a little cottonseed meal and oilmeal. The floors are covered with concrete and brick both in stable and lot. Shavings and sawdust were used for bedding and in addition the manure was dusted with land plaster in the drop. It was carefully weighed and removed from the stable twice a day and on three days was sampled. Both manure and feeds were analyzed. Following is a summary of the average manure production from each cow.

| | | |
|---|---|---|
| Clear excrement produced daily | 76.2 | pounds |
| Excrement produced daily, with bedding | 83.4 | pounds |
| Yearly production of excrement per 1,000-pound animal | 13.75 | tons |
| Organic matter consumed daily | 21.3 | pounds |
| Organic matter voided daily | 9.25 | pounds |

| | |
|---|---|
| Organic matter regained | 43.3 percent |
| Nitrogen consumed daily | 0.59 pound |
| Nitrogen voided daily | 0.26 pound |
| Nitrogen regained | 44.3 percent |
| Ash regained | 63.6 percent |
| Water in manure | 81.8 percent |

The return of 43.3 percent of the organic matter can be approximately checked by calculation from the digestibility tables of Armsby and Henry. The return of nitrogen, which appears low, is checked by calculation of the nitrogen in the milk produced. The return of mineral elements appears to be low and is not so well checked by the amount in the milk.

### Loss of Organic Matter in Handling Manure.

The organic matter in the feed must be followed further. There is a variable and unusually large loss in handling manure. Schutt[10] exposed mixed manure from cows and horses in bins, one of which was open to the weather, while the other was sheltered from the rain and snow. The loss of organic matter in six months was 65 and 50 percent, respectively. Even when handled in the best way, there is a considerable loss which varies with the type of animal. Calculations of the Ohio results[11] in the production of manure by 28 and 30 steers fed on a clay and on a cement floor, respectively, for six months show a recovery of only 12.7 percent and 10.9 percent, respectively, of the organic matter in the feed consumed.

The evidence is substantial that the average farmer does not return to the land more than 15 to 30 percent of the organic matter in the feed consumed by his animals. The loss from storage of such fermentive materials as horse manure is very large. Consider a heap of manure in the winter that produces sufficient heat to melt frequent heavy snowfalls in the presence of temperatures around zero and that maintains an internal temperature hot to the touch. Contemplate the number of tons of coal required to supply this same amount of heat. The destruction of organic matter is as definite and effective in the heap as in the furnace for the same heat production.

This is not necessarily an indictment against livestock husbandry. That business must rest on other factors than soil fertility. It suggests that perhaps the animal has been given too large a place in the maintenance of the soil. While the nutrients in manure are valu-

[10] Schutt, M. A. Barnyard manure. *In* Dept. Agr. (Canada) Central Expt. Farms Bul. 31. 1898.

[11] Thorne, C. E. Farm manures, p. 100. 1913. Orange Judd Co., New York.

able if they can be saved, they are not indispensable. They can be purchased. The purchased feeds are usually not adequate to equalize the destruction of organic material by the animal. Concentrated feeds are most likely to be purchased. These are the materials on which the animal is most destructive. Therefore, while these purchased materials are an additional aid to keeping up the soil organic matter, they put off but do not necessarily avoid the evil day of a deficiency.

The most critical factor in the system of soil management is organic matter. In view of the destructive action of animals, it may be better practice where the lack of organic matter is the controlling factor in yield to turn under a crop than to feed it. One crop in six may be turned under and the land be as well off as if the manure from those crops was applied.

The question of the animal as a means of marketing crops must be considered. Where animal products are very high and crop products relatively low animal husbandry is most to be advised. On the other hand, where crops are relatively high in price and especially where the land is very poor,—if it is under cultivation—one can scarcely afford to keep stock; but where the land is not cultivated but is merely grazed without any attempt to keep up its productiveness the situation is different.

These conclusions are contrary in some respects to the usual teachings. It is a business proposition whether you will keep stock. The animals should be entirely able to pay their own way. When the manure must be closely figured to show a profit from keeping livestock, one is on doubtful ground.

The purchase of feeds is an aid in the maintenance of the soil but if the loss is not made good where the feed is produced, it is a system of "borrowing from Peter to pay Paul" and is not good national economy. Animal husbandry must stand on its own bottom and pay its way to the soil, whether its supply of feed is produced on the farm where it is used or obtained from another part of the country.

### Summary.

In conclusion, the points that should be emphasized are:

1. The higher plants are able to use organized carbonaceous foods, both nitrogenous and non-nitrogenous.

2. Carbonaceous food conserves energy in the process of growth of the crop and makes possible a larger total growth in a given time.

3. The organic matter in the soil is the direct source of the car-

bonaceous material used by the plant. Any process that permits the destruction of organic matter that might find its way into the soil is likely to be poor economy.

4. Animals destroy from half to nine tenths of the organic matter in the feed consumed. It is burned up in the body processes and expended as energy.

5. A further large loss occurs in the handling of the manure.

6. It is entirely possible to maintain the organic matter in the soil without animal husbandry. On very poor soils, animal husbandry may be bad practice. It may be justified by large profits from the animal products by means of which the loss of organic matter can be made up from other sources.

CORNELL UNIVERSITY,
ITHACA, N. Y.

## HEATING SEED ROOMS TO DESTROY INSECTS.[1]

E. G. MONTGOMERY.

The problem of protecting stored seeds and grains from insects is one that confronts almost every agronomist. Often hundreds of small lots are kept over from year to year or even for several years. If the seed room becomes thoroughly infested, it often requires constant care to prevent the total loss of these samples.

Fumigation with carbon bisulfid or hydrocyanic acid gas is the most common method of protection used. This, however, has certain disadvantages and is not always effective. Both of these gases are dangerous to human life and, therefore, are not always safe to use when the storage room is in a classroom or office building. The fire danger from carbon bisulfid is so great that it cannot be used safely in large quantity, when it is likely to leak into adjoining laboratories or offices. The hydrocyanic acid gas is also corrosive and its continued use will generally destroy sacks and also the germination of seed.

Experience has also shown that fumigation is only partly effective, as it seldom kills all the eggs or larvæ. The gas can not penetrate into closed containers such as cans or bottles, and penetrates only very slowly into large masses of grain.

[1] Contribution from the Department of Farm Crops, New York State College of Agriculture, Cornell University. Presented at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1916.

The heating method for killing insects has been well known for 25 or 30 years, and in recent years has been advocated as a means of flour-mill fumigation.[2] The experimental work has shown that grain insects exposed to a temperature of 120° F. for 15 to 20 minutes will be killed. This temperature also kills the eggs, larvæ, and pupæ. This complete destruction of all stages of the insects is a great advantage as one thorough treatment a year will ordinarily be sufficient.

The Farm Crops Department at Cornell University fitted up a small seed store room with heating apparatus two years ago. We thought it would be a simple matter at first, but a number of problems developed. The room used was 8 feet by 18 feet by 10 feet high. The walls were light, temporary partitions, but were made tight with a coat of cement plaster. There are one window and one door in the room through which much heat escapes in cold weather, but there is little trouble in warm weather.

For fumigating mills it is stated in both the Ohio and Kansas bulletins referred to that 1 square foot of radiating surface to 70 cubic feet is sufficient to secure a killing temperature in midsummer. From 12 to 15 hours were needed, however, to attain this temperature. In our store room, however, we have 1 square foot of radiation to 5.5 cubic feet of space and do not find it too much in winter, but it is more than is needed in summer. Probably a ratio of 1 to 10 would be enough for the warmer months.

The steam coils are connected to the regular steam radiator system used for heating the building. We also have it connected with a gas boiler for heating when steam is turned off in the summer time. However, we have found the gas boiler unnecessary as one or two heatings a year are sufficient.

One of our greatest difficulties was to secure a uniform heat in all parts of the room. Thermometers were hung at different heights in the room and were also thrust into sacks and boxes of grain to ascertain how long it would take for all parts to reach a killing temperature of 120 to 130 degrees. We soon found that the temperature near the ceiling was 20 to 30 degrees higher than near the floor. As the germinating quality of grain is destroyed at 150° F. and probably injured at 5° less if long exposed, it was found necessary to introduce an electric fan to keep the air circulating. The fan alone,

[2] Goodwin, W. H. Flour mill fumigation. Ohio Agr. Expt. Sta. Bul. 234. 1912. Dean, Geo. A. Mill and stored grain insects. Kans. Agr. Expt. Sta. Bul. 189. 1913.

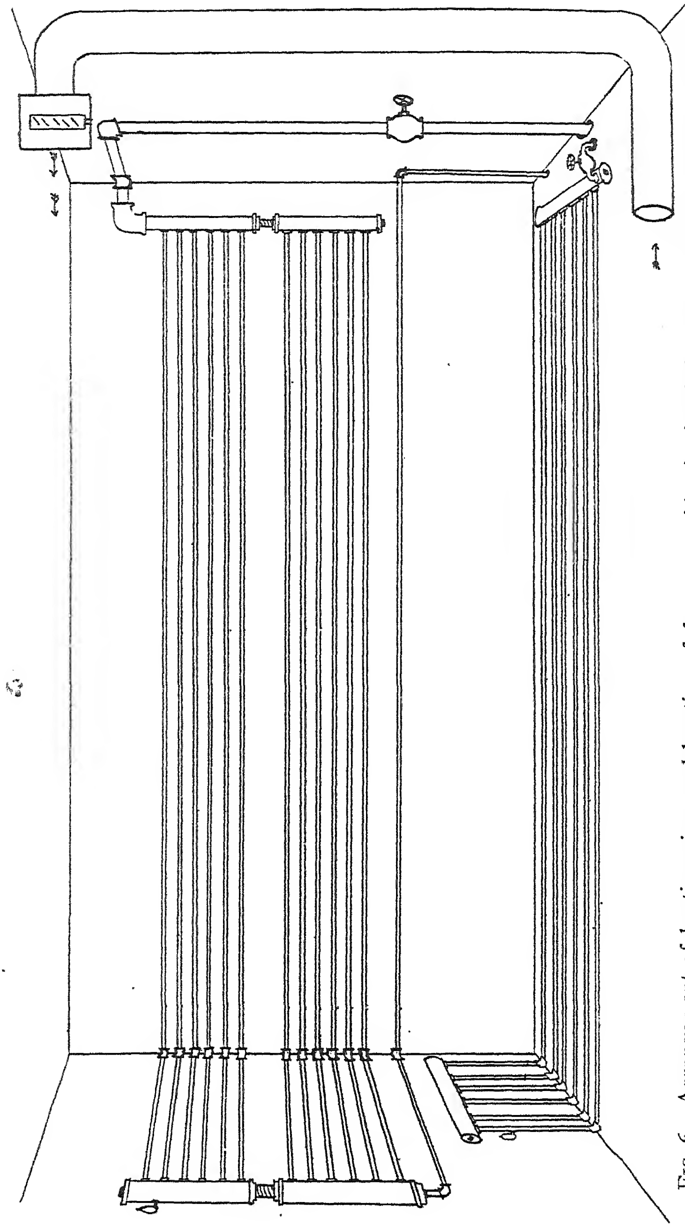

Fig. 6. Arrangement of heating pipes and location of fan to provide air circulation and maintain a fairly uniform temperature throughout the seed room when heating to destroy insects.

however, did not provide sufficient circulation until it was set near the ceiling, with an 8-inch stove pipe at the back and extending to the floor (fig. 6). By this means the cooler air was sucked from the floor and delivered at the ceiling, resulting in a fairly uniform temperature in all parts.

Further experiments showed that it took about 10 to 12 hours for an outside temperature of 130° to raise the temperature in a 2-bushel sack of grain to 120° F. In closed boxes or cabinets a killing temperature would hardly be reached in 24 hours. To overcome this difficulty we made our larger grain receptacles (half-bushel size) with bottoms and tops of perforated metal. By placing these receptacles on slatted shelves a fairly free circulation is secured, and a half bushel of grain will usually reach 120° in 5 or 6 hours with a room temperature of 130° F.

It is of interest to note that mice are killed as well as the insects and that the germination of the grain has not been injured. Some of the ear corn on upper shelves was subjected to a temperature of 140° F. several times without apparent injury. After several years' experience with chemical fumigation, I find the heating method very much more satisfactory and perfectly practical where it would be dangerous to use chemicals.

Department of Farm Crops,
Cornell University,
Ithaca, N. Y.

# GREEN MANURING: A REVIEW OF THE AMERICAN EXPERIMENT STATION LITERATURE—2.

A. J. PIETERS.

*(Continued from the February issue.)*

## NORTHEASTERN DIVISION.

The northeastern division, for the purposes of this paper, includes the states north of the Ohio River and east of the Missouri, except those bordering on the Atlantic Ocean. The Province of Ontario is also included in this division. Here, red clover is the chief legume used in the farm rotation, and is the only one entering into the experimental work of these stations to any great extent.

### CANADA.

The most conclusive evidence we have regarding the value of red clover as a green manure is furnished by the work of the Central Experimental Farm at Ottawa. Although, so far as has been determined, the experiments usually ran for but one year, the number of tests made and the length of time during which these isolated experiments were carried on combine to make this a body of evidence of high value. Work on green-manure experiments is reported in various annual reports from 1893 to 1912 as well as in bulletins 40 and 165.

For the purpose of this study the Canadian experimental farms may be considered in two groups. At the Central Experimental Farm at Ottawa and at the Nappan (N. S.) Farm the work with green manures and with legume catch crops has been almost wholly with red or mammoth clover. At the Western farms,—Brandon, Man.; Indian Head, Sask.; and Agassiz, B. C.,—a number of legumes as well as some nonleguminous green-manure plants have been tried. At both the Central Experimental Farm and the Nappan Farm attention was paid to the influence of the clover on the grain crop with which it was growing. (Reports 1895, 1896, 1897, 1898, 1903, and 1904.) While the yields were often irregular, there was no evidence that the grain crop was especially affected by the clover. At the Agassiz Farm the yield of grain was less when clover was growing with it (Rpt. 1896, p. 440), but at both the Brandon and the Indian

Head farms the results were similar to those reported from the Central Farm.

At the Central Farm in 1897 eight twentieth-acre plots were selected, four being seeded to grain with red clover and four to grain without the clover. The clover crop was turned under and oats sown in 1898. In 1899 barley was grown. Not only did the clover increase the yield of oats by nearly 30 percent on the average but the residual effect on the barley of 1899 was marked (Report, 1899).

Other experiments gave similar results. In 1899 potatoes yielded 28 percent better after clover than after carrots and in 1900 the yields of potatoes after a catch crop of clover with grain were uniformly higher than after grain without the clover (Reports 1899 and 1900). In all these catch-crop experiments there was but one plot of a kind at a time, which naturally detracts from the value of the individual experiment. However, the fact that these trials were made for several years and in some of these years in several independent series of tests and that the results were uniformly in favor of the clover gives this evidence high value.

It will be impossible to quote at length from the tables presented in these reports; a few will serve as examples. In 1902 oats, corn, and potatoes were grown on land on which grain, with and without a catch crop of clover, had been grown in 1901. The yields were much more after the clover than on the plots without clover, as shown in Table 4. (Report, 1902, p. 39.)

TABLE 4.—*Yields of oats, fodder corn, and potatoes on the Central Experimental Farm in 1902, on plots on which wheat, barley and oats were grown the previous year, with and without clover.*

| Previous crop. | Oats. | Fodder corn. | Potatoes. |
|---|---|---|---|
| | *Bushels* | *Tons.* | *Bushels* |
| Wheat, no clover | 63.53 | 16.40 | 353.33 |
| Wheat, clover | 72.94 | 22.80 | 396.00 |
| Barley, no clover | 61.18 | 17.36 | 346.67 |
| Barley, clover | 70.59 | 23.60 | 386.33 |
| Oats, no clover | 58.88 | 15.00 | 358.33 |
| Oats, clover | 70.59 | 20.40 | 392.67 |

The tenor of the reports for the following years is the same. In every instance the plot on which a catch crop of clover had been grown outyielded the other plot. At the Nappan Farm a similar line of work was carried on during the seasons of 1905, 1906, 1908, 1909, and 1910. In practically every instance the yield was best after clover.

The report for 1903, pages 33–37, gives the results of an extensive experiment consisting of several divisions, each having a number of plots, on some of which clover had been grown for one season (1900) and then turned under, on others for two seasons (1900 and 1901), while on check plots no clover had been grown in 1900. The yields of various crops were all larger during the subsequent three (and two) years on the clover than on the no-clover plots. Table 5 shows yields of corn, oats, potatoes, carrots and sugar beets in 1901, 1902, and 1903, following clover turned under.

TABLE 5.—*Yields of fodder corn in 1901, oats in 1902, and potatoes, carrots, and sugar beets in 1903 on the Central Experimental Farm on plots cropped to clover or without clover in preceding years.*

| Previous crop. | Fodder corn in 1901. | Oats in 1902. | 1903. | | |
|---|---|---|---|---|---|
| | | | Potatoes. | Carrots. | Sugar beets. |
| | *Tons.* | *Bushels.* | *Bushels.* | *Tons.* | *Tons.* |
| Clover in 1900 | 25.80 | 70.59 | 195.33 | — | — |
| No clover | 20.08 | 58.82 | 175.33 | — | — |
| Clover in 1900 and 1901 | — | 65.88 | 221.33 | — | — |
| Clover in 1900 | 27.22 | 70.59 | — | 31.48 | — |
| No clover | 15.40 | 47.06 | — | 20.32 | — |
| Clover in 1900 and 1901 | — | 72.94 | — | 21.30 | — |
| Clover in 1900 | 27.88 | 75.29 | — | — | 22.30 |
| No clover | 19.64 | 51.77 | — | — | 8.60 |
| Clover, 1900 and 1901 | — | 68.23 | — | — | [a]0. |

[a] No germination.

In this and in other cases the effect of the clover was marked for three years. In 1904 records of yields for three years following the turning under of a clover catch crop in 1901 were available. Corn in 1902 was followed by potatoes and these by barley in 1904 and all yielded larger crops on the clover than on the no-clover plots (Report, 1904, p. 34).

The Nappan Farm (Report, 1905, p. 283) showed that a catch crop of clover in the grain turned under for grain the following year resulted in larger yields than where grain was grown continuously. The yields for 1905, the third year of the experiment, are given in Table 6.

TABLE 6.—*Yields of wheat, oats, and barley in bushels per acre on the Nappan Farm in 1905, on plots continuously cropped to grain with and without clover for three years.*

| Green manure. | Wheat. | | Oats. | | Barley. | |
|---|---|---|---|---|---|---|
| | Plot 1. | Plot 2. | Plot 1. | Plot 2. | Plot 1. | Plot 2. |
| None | 34.33 | 39.00 | 41.18 | 60.30 | 32.71 | 38.54 |
| Clover | 40.00 | 41.67 | 55.29 | 60.85 | 37.92 | 42.92 |

Similar experiments with similar results are recorded in Report, 1908, p. 261, and in Report, 1911, p. 332.

At the Central Farm records were also kept of the yields of grain on a series of plots that had been heavily fertilized with commercial fertilizers for about ten or eleven years. At the end of this time the fertilizers were no longer applied but a catch crop of clover was substituted. The records are found in the Report for 1903, p. 32. With heavy applications of complete fertilizers the average yield of oats for eleven years was 44.88 bushels. The average for the five years following, when no fertilizer was applied, but clover was turned under, was 56.69 bushels. The average annual yield of wheat was increased under this system by more than 40 percent and that of barley by 48 percent. While it is probable that in these cases the clover served to make the residues of the previously applied fertilizers available, this is in itself a useful function.

Besides the annual reports referred to, the subject of red clover as a fertilizer is discussed in Bulletin No. 40 of the Central Farm and by F. T. Shutt in *Science* for August 30, 1907, p. 265. The material in these publications is, however, identical with that of the Reports.

Alfalfa and timothy sods were compared (Bulletin, Ontario Agr. College, No. 165) in 1900–1903. Sods of both were plowed each year and wheat, barley, and corn planted. The yields were as follows:

| | 1901 Winter wheat. | 1902 Barley. | 1903 Corn. |
|---|---|---|---|
| After alfalfa | 61.5 bu. | 30.2 bu. | 24.0 bu. |
| After timothy | 42.1 bu. | 19.7 bu. | 17.9 bu. |

Although a discussion of the quantity of nitrogen added to soils by clover is not included in the scope of the present paper it may not be out of place to refer to one very instructive experiment recorded in the Canadian report for 1911, p. 173. This experiment was started in 1902 at the Central Farm (see also F. T. Shutt's article in *Science*, Aug. 30, 1907, p. 265). A plot 16 feet by 4 feet was staked off and the sides protected by boards sunk to a depth of 8 inches. The surface soil was removed and new sandy soil the nitrogen content of which was 0.0437 percent was substituted. Superphosphate and muriate of potash were added and red clover sown. During each season the crop was cut twice and the material allowed to decay on the ground. Every second season the crop was turned under, the soil being stirred to a depth of 4 inches, and clover was again seeded the following spring. Table 7, taken from the report for 1911, p. 173, gives the data obtained during nine years of clover growth.

TABLE 7.—*Increase in nitrogen in soil due to growth of clover, as shown by the percentage of nitrogen in water-free soil and the pounds per acre in the surface 4 inches.*

| Period from beginning of experiment. | Date of collection. | Percentage of nitrogen in water-free soil. | Pounds of nitrogen per acre to depth of 4 inches. |
|---|---|---|---|
| Before experiment began........ | May 13, 1902 | 0.0437 | 533 |
| After two years................ | May 14, 1904 | .0580 | 708 |
| After four years................ | May 15, 1906 | .0608 | 742 |
| After five years................ | May 30, 1907 | .0689 | 841 |
| After six years................. | May 23, 1908 | .0744 | 908 |
| After seven years.............. | May 4, 1909 | .0750 | 915 |
| After nine years................ | May 5, 1911 | .0824 | 1,005 |
| Increase in nine years.......... | ——— | .0387 | 472 |

ILLINOIS.

At the Illinois station rotation plots have been carried on since before the organization of the station and are mentioned in 1888 in the first annual report as number 23 of the University of Illinois experiments. From time to time the results from these and from other plots added later have been reported or conclusions have been drawn from data based on the yields from these plots.

In Bulletin 31 (p. 357), 1894, is reported the yield of corn and oats on ten plots for the years 1888 to 1893, inclusive. To some plots stable manure was applied and to others commercial fertilizers, while on some clover preceded the corn. The use of clover appears to have had nearly the same effect as the application of 24 loads of stable manure annually and the average yields of corn from the clover rotation plots was much better than from the corn-oats plots.

In 1890 and 1891 there was corn on clover rotation plot 7, on corn-oats plot 4 and of course on the continuous corn plots 1, 2, and 3. Plot 1 received stable manure. The average yields for those years were: Plot 1, 49.6 bushels; plot 2, 35.3 bushels; plot 3, 38.6 bushels; plot 4, 43.7 bushels; and plot 7, 47.9 bushels.

In 1888 and in 1893 there was corn on clover rotation plots 9 and 10, on the corn-oats plot, and on plots 1, 2, and 3. The average yields for the two years were as follows: Plot 1, 45.3 bushels; plot 2, 38.3 bushels; plot 3, 37.9 bushels; plot 4, 39.5 bushels; plot 9, 51.6 bushels, and plot 10, 48.0 bushels. It is clear that the rotation including clover has maintained the fertility of the soil better than manure or commercial fertilizers and this effect is well marked in a poor corn year as 1893. The author states that the same was true in 1887.

In Bulletin No. 42 (1896), p. 177, is given a table covering the yields on plots of Experiment No. 23, up to and including 1895. The increase in the corn crop when grown in a 3-year rotation was 20

bushels per acre over the corn-oats rotation for the corn crops immediately following the clover and 15.2 bushels for the second year of corn after clover. Other references to Experiment No. 23 will be found in Bulletins 8, 13, and 37.

In Bulletin 88 (1903) is reported work done on several experimental farms. Since the year 1903 was an unusually poor one for wheat the data are not of much value for our purpose except those from the Cutler field. It is shown (p. 140) that on this field the turning under of a crop of cowpeas in 1902 increased the net returns from the wheat crop of 1903 over that from a corresponding plot from which the cowpea crop was removed. The question whether the value of the cowpea hay turned under was more or less than the increased returns from the wheat is not discussed.

Bulletin No. 99 (1905) contains the record of experiments on certain fields on the Lower Illinois glaciation. On the Edgewood west field cowpeas were grown on one plot in 1896 and buckwheat on another and the crops were turned under for corn the following year. This was repeated in 1898 for the corn crop of 1899. The season of 1897 was so unfavorable that no conclusions can be drawn. In 1899 on the undrained series of plots the corn crop on the cowpea plot of 1898 was more than 50 percent greater than on the sodium nitrate plot having the highest yield. On the drained series, however, one of the untreated plots returned the highest yield and the cowpea plot ranked fifth in a list of seven plots. In 1902 a catch crop of cowpeas was grown in the corn but the oat crop of 1903 showed no improvement. On the Odin field also the legume catch crop did not produce an increased yield of the following crops. It should be added, however, that the authors point out that the season of 1902 was "very dry and the cowpeas made but little growth."

On the Cutler field, reference to which was also made under the discussion of Bulletin No. 88, corn was grown in 1904 on the wheat plots of 1903. While the yield of corn was slightly better on the plot on which cowpeas were turned under in 1902 than on that from which the hay was removed, it was much less than the yield from the plot receiving manure instead of the cowpea vines. This was equally true of the plots with and without lime. It is presumed that 2 tons of manure per acre per year, all applied at one time on the corn, was used. The 1904 wheat crop was much injured by rust and consequently conclusions drawn from these plots would be open to objection.

Further records from some of these experimental fields are given in Circular No. 97 (1905). The yields of wheat following a legume

(cowpea) catch crop were sometimes less and sometimes more than those on the check plot, but the differences were mostly too small to be significant. In 1904 some plots on the Cutler field (page 9) received nitrogen (100 pounds per acre in 700 pounds dried blood) instead of the legume catch crop. A comparison of three plots receiving a legume plus mineral fertilizers, including lime, with three in which nitrogen replaced the legume shows slightly higher yields for the nitrogen plots, but here again the differences are not marked enough to warrant any conclusions from a 1-year test.

On the Vienna field (p. 11) the turning under of a legume (cowpea) crop appears to have increased the crop of wheat in 1905 very much, from 1.3 bushels per acre on the nonlegume to 10.8 bushels on the legume plots. These figures, with others, are also given in Soil Report No. 3 (1912), p. 9, and in Soil Report No. 11 (1915), p. 11. The increase in the yield of wheat is striking, especially so since the corn yield of both 1902 and 1903 was larger on the nonlegume than on the legume plots, indicating if anything slightly better soil on the former. However, in 1909 cowpeas were again removed from Plot 1 and turned under on Plot 2, but the corn crop of 1910 was only 1.9 bushels higher on Plot 2 than on Plot 1. In view of the fact that the results with wheat after turning under cowpeas on plots of series 200 and 300 were not so marked as on those of series 100 and in view of the small increase in the corn crop on all of these series after turning under a crop of cowpeas the large increase in the yield of wheat on plot 102 must be taken cautiously. The results do show a general increase of yield, however, on the plots on which the crop of cowpeas was turned under.

Pot experiments with a worn soil were carried on from 1902 to 1905 and are reported in Circular No. 97, pages 12 to 19. Part of these data are also given in Soil Reports No. 3, No. 7, No. 11, and No. 12. On some pots a catch crop of cowpeas was turned under with lime. The crop of wheat during 1903, 1904, and 1905 was markedly better on the legume-lime pots than on those receiving no treament, but how much of this gain is due to the lime can not be determined. One set of pots received a legume with lime, phosphorus, and potassium while in another set nitrogen in commercial form was substituted for the legume. While the crops of 1903 and 1904 were generally better and in some cases very much better from the "nitrogen" pots, that of 1905 was either better from the legume pots or as good as that from the nitrogen pots. In Soil Report No. 12 the above data are repeated and the yields for 1906 and 1907 are

included. These show that in general the legume continued to give better results than considerable quantities of commercial nitrogen.

In Bulletin No. 115 (1907) further details are given concerning the experiments on the Vienna field. It is claimed that the use of legume green-manure crops (cowpeas) doubled the total yield of wheat for 1904, 1905, and 1906. The figures given are correct, but the increase in 1904 on the 200 series was negligible, and that of 1906 on the 200 series was not large, while the greater part of this total increase was made on the 100 series, in 1905. No information is given as to the difference, if any, between plots of the 100 and 200 series but it may be questioned whether it is desirable to average figures taken from plots on different series. The yields of corn during 1904, 1905, and 1906 were also slightly higher on the legume plots than on the nonlegume plots, though the total difference for the three years was slightly under 10 bushels.

The pot-culture experiments mentioned above from Circular No. 97 are again reported with the addition of the record for 1906. On the pots receiving phosphorus and potassium in 1906 the legume catch crop appears to have supplied the nitrogen, while where nitrogen and lime only was applied the yield was much lower than from the legume-lime pots.

In Bulletin No. 125 (1908), Hopkins, Readhimer, and Eckhardt give an account of thirty years of crop rotations at the Illinois station. Part of the work reported is that on the oldest plots commenced in 1879 and part on the new series laid out in 1895 and brought under definite systems of crop rotation and soil treatment in 1900. The record of the yields on the older series is also given by Hopkins in the latest edition of his book on Soil Fertility and Permanent Agriculture, p. 457. While working up these data the writer was able to secure also the records for 1913 and 1914, so that tables presented below have been compiled from the records as given by Doctor Hopkins in his book, with the addition of those for the last two years. In 1904 the plots of the older series were divided and the south half planted to a legume catch crop each year together with lime, manure, and phosphorus. The north half had no treatment. Comparing the corn yields from the 2-year corn-oats rotation with those from the corn-oats-clover rotation it is evident that the yields have been maintained at a higher level by the latter rotation than by the former. The addition of the treatment to the south half of each plot also increased the yield but the presence of several other factors makes it impossible to draw conclusions in regard to the use of a legume catch crop on these plots.

Table 8 gives the yields of corn on the plots of the 2-year and the 3-year rotations, since 1904. While this record seems quite satisfactory so far as showing the benefit to corn, when the yields of oats for the same period are studied it is seen that the 2-year corn-oats rotation has given slightly better yields than the corn-oats-clover rotation.

TABLE 8.—*Yields of corn and oats in bushels per acre obtained in a 2-year corn-oats rotation and in a 3-year corn-oats-clover rotation, with and without a legume catch crop.*

CORN.

| Two-year rotation. | | | Three-year rotation. | | |
|---|---|---|---|---|---|
| Year | Non-legume plots. | Legume, manure, lime, and phosphates. | Year. | Non-legume plots. | Legume, manure, lime, and phosphates. |
| 1905 | 50.0 | 44.9 | 1904 | 55.3 | 72.7 |
| 1907 | 47.8 | 87.6 | 1907 | 80.5 | 93.6 |
| 1909 | 33.0 | 64.8 | 1910 | 58.6 | 83.3 |
| 1911 | 28.6 | 46.3 | 1913 | 33.8 | 47.8 |
| 1913 | 29.2 | 25.0 | | | |
| Average | 37.7 | 53.7 | | 57.05 | 74.35 |
| Average yearly increase for 3-year over the 2-year rotation | | | | 19.35 | 20.65 |

OATS.

| | | | | | |
|---|---|---|---|---|---|
| 1906 | 34.7 | 52.5 | 1905 | 42.3 | 50.6 |
| 1908 | 32.9 | 15.0 | 1908 | 40.0 | 44.4 |
| 1910 | 33.8 | 59.4 | 1911 | 20.5 | 37.9 |
| 1912 | 55.0 | 81.0 | 1914 | 39.6 | 60.4 |
| 1914 | 33.6 | 58.2 | | | |
| Average | 38.0 | 53.2 | | 35.6 | 48.3 |

On the new series of plots a legume catch crop (cowpeas at last working of corn or clover with oats) was introduced in 1901, but the record up to 1907 does not show any benefit from this treatment, for the "effect has been a decrease as often as an increase" in the regular crop.

For drawing conclusions as to the value of a legume in the rotation the data available in 1908 on the newer series can scarcely be used, for a corn crop was grown on all comparable plots in only one year. In that year (1904) the average yield of corn on all plots of the 3-year rotation (series 300) exceeded that on all plots of the 2-year series (500) by 29.5 bushels and the oats yield in 1895 on the 3-year rotation plots exceeded that in the 2-year plots by 7.8 bushels, a result different from that obtained with oats on the older series of plots. However, it should be noted that between 1898 and 1904

the plots of series 300 produced but one corn crop while those of series 500 produced four.

A comparison of the effect of a legume catch crop in oats with that of manure may be made for the years 1905 and 1907. In 1904 and 1906 clover was sown in oats on the plots of series 400, numbers 2, 4, 6, and 8. On number 4 lime was added, on 6 lime and phosphorus, and on 8 lime, phosphorus, and potash. Plots 3, 5, 7, and 9 are the corresponding plots where manure was used instead of the legume. The average yields of corn from the above plots in 1905 and 1907 were as follows: In 1905 on all legume plots, 63.2 bushels, and on all nonlegume plots, 71.7 bushels; in 1907, 78.6 and 69.0 bushels, respectively. The average yields for the two years were: On legume plots, 70.9 bushels, and on nonlegume plots, 70.2 bushels. Apparently the legume catch crop and the manure have been equally efficient.

Circular No. 96 (1905) presents many of the same data given in Bulletin No. 125, and will not require special mention.

Although not directly in line with this study it may be admissible to mention here an interesting experiment recorded in Bulletin 182 (1915). In the course of a series of pot experiments with the "insoluble residue" from soil from which the acid-soluble potassium had been extracted, it was found that the clover failed or grew very poorly at first. By turning under what did grow and by improving the mechanical condition of the soil with sand from which the potassium had also been extracted, at the end of three years there was a fair growth and the total amount of potassium removed from the soil was many times greater than that which had been added in seed and impurities. The authors state that 99 percent of the potassium recovered in the crop was secured from the "insoluble residue." This was made possible by two years of green manure.

In Soil Report No. 14, Hopkins and others report on a test of green manures and commercial nitrogen on wheat. Wheat was grown in pots to some of which commercial nitrogen (amount not stated, but said to have been in excess of the value of the crops produced) was added. In other pots cowpeas were grown in late summer and fall and turned under for wheat. After the second year the crops raised after cowpeas were better on the average than those that had received commercial nitrates.

### INDIANA.

This station appears to have conducted two long series of rotation and fertilizer experiments. The older, commenced in 1880, is mentioned in Bulletins 27 and 64. Besides continuous wheat culture,

rotations of corn, oats, and wheat and of corn, oats, wheat, and clover-timothy were conducted. In Bulletin 64 (1897) the yields for the previous nine years are reported as having been 6.22 bushels of corn more for the rotation with "grass" than for the grain rotation. At the end of the 9-year rotation period the entire field was put into corn. The corn in 1896 yielded an average of 5.66 bushels more on the "grass" rotation plots than on the grain rotation plots (Report, 1896). The gain in wheat is said to have been 7 bushels an acre (Annual Report, 1895).[4]

In Bulletin 88 is a record of another experiment in which a corn-oats-wheat rotation was compared with a rotation of corn-oats-wheat-clover. Both rotations were fertilized at nearly, though not always at exactly, the same rate. The yields of corn, oats, and wheat for four complete rotations are recorded and the average annual yields are given below.

| | Grain rotation. | Grain and clover. |
|---|---|---|
| Corn, 4 crops | 50.52 bushels | 34.34 bushels |
| Oats, 4 crops | 55.08 bushels | 45.62 bushels |
| Wheat, 4 crops | 30.99 bushels | 20.37 bushels |

It is evident that the effect of the clover has been masked by that of the fertilizers, but it is not clear why the clover rotation should have given such poor returns.

In Bulletin No. 114 (1906) what appears to be another rotation series is reported. Wheat was grown continuously or rotated with corn, with corn and oats, or with these and clover or with clover and timothy. The average wheat yields for the period of the experiment (18 years?) are as follows:

| | |
|---|---|
| Continuous wheat | 22.7 bushels |
| Corn, wheat | 16.5 bushels |
| Corn, oats, wheat | 22.0 bushels |
| Corn, oats, wheat, timothy and clover | 25.6 bushels |
| Corn, oats, wheat, clover | 29.1 bushels |
| Corn, oats, wheat, clover | 25.2 bushels |

In these experiments continuous wheat culture appears to have given better results than a grain rotation. The introduction of clover into the rotation caused some increase in the yield of wheat. The average of the last three wheat yields was 16.9 bushels on the corn-wheat and 22.1 bushels on the corn-oats-wheat-clover rotation.

[4] References to this series of experiments of more or less importance are found in the following bulletins and reports: Bulletins 16, 1888; 27, 1889; 32, 1890; 39, 1892; 43 and 45, 1893; 50 and 51, 1894; 55, 1895; 64, 1897; Annual reports for 1888, 1894, 1895, and 1896.

IOWA.

Brown in Research Bulletin 6 (1912) presents a study of the effect of rotations on the bacterial activity of soils. This work was carried on in a field that had been in various rotations from 1907 to 1911 and the yields for 1911 from the various rotations are given. It appears that the plots having a corn-oats rotation with a cowpea catch crop returned the lowest yield, a trifle less than the continuous corn plot. The corn-oats-clover with clover catch crop returned 20 bushels per acre more than the lowest plot. The results have little value, however, as the time covered (4 years) is short for the effect of rotations to become evident.

The yields of corn for 1912 and 1913 are given in Research Bulletin 25 and these show that in 1912 the best yield was obtained from the plots on which a clover catch crop was turned under and that a cowpea catch crop was followed by yields nearly as large as those taken from the 3-year rotation plots. In 1913, however, the 3-year corn-oats-clover rotation gave the largest yields, followed by the plot on which rye had been turned under. The yields from the clover and the cowpea catch crop plots were less than where rye had been turned under.

In Bulletin 161 it is stated that for Iowa soils yields are better in rotations than in continuous culture, but it was also found that cowpeas sown at the last working of the corn depressed the yields of corn slightly over the 8-year period. During the first 4-year period the yield after a cowpea catch crop was slightly better than from the check plots, but during the second 4-year period the reverse was the case. When manure or manure and cowpeas were used the cowpeas depressed the yield during both periods, but when phosphorus was added slightly higher yields were obtained from the cowpea plots than from those with manure and phosphorus but without cowpeas.

Oats yielded slightly better for the 8-year period on land having had a cowpea catch crop than on the check, but when manure or manure and phosphorus were added to the cowpeas the yields were lower on the cowpea plots than on those without cowpeas. The authors attribute this depressing effect to "unsatisfactory moisture conditions and lack of available plant food."

The effect of turning under various catch crops and of the use of clover as a crop in a 3-year rotation of corn-oats-clover is shown in Bulletin 167 (1916). Besides the 3-year rotation there were four 2-year rotations of corn and oats, one without a catch crop, one in which clover was sown with the oats, and two in which cowpeas and

rye respectively followed the oats as catch crops. All three catch crops were turned under in the fall preceding the corn. It is stated that satisfactory quantities of green material were plowed under in each case. Comparing the yields on the 2-year rotations it is noted that the use of cowpeas and of rye did not increase the corn yields during the six years of the experiment, but that the yield following the clover catch crop was more than 11 bushels better than that on the plain 2-year rotation. The yield of oats was practically the same on the 2-year rotations with catch crop and on all was slightly better than that from the check rotation. The yield of corn from the 3-year rotation was a little less than that from the 2-year clover catch crop plots, but the yield of oats was more than 10 bushels better than that from the 2-year catch crop rotation. The financial results given show that the 3-year rotation was most profitable, closely followed by the 2-year rotation in which a clover catch crop was used.

### MICHIGAN.

In 1896 this station started an experiment which we must regret has not yielded more positive results. The plan as given in the Report for 1911, p. 212, was simple but calculated to answer fundamental questions. On one series wheat was grown continuously, on two plots wheat alternated with clover, on two orchard grass was grown continuously, and on two other plots clover was to have been grown continuously. There were also two fallow plots on which no crop was grown for ten years. Some other rotations were also tried, as well as continuous corn culture. There are indications that the land was not uniform or if so that the method of treatment left much to be desired. From 1890 to 1896 all plots were cropped the same so as to determine the uniformity of the soil. But in 1896 wheat yielded 2,620 pounds, 3,440 pounds, and 2,300 pounds on plots 62, 64 and 66, while the average yield of plots 1, 7, 36, 60, and 68, was but 111 pounds. No explanation is offered for these wide variations, but the work was carried out on this land. After ten years of cropping as above stated all plots were planted to corn in 1906, oats in 1907, and wheat in 1908, to determine the effect of the previous cropping on fertility. During these 10 years the clover had failed twice on the wheat-clover rotations and there is no record of a clover crop for six years out of ten on plot 34 and for four years out of ten on plot 72, both continuous clover plots. Whether the clover failed (and if so, how the plot was treated) or whether the record was lost is not stated. The average yields in pounds per acre of all plots of a kind in 1906, 1907, and 1908 are given in Table 9.

TABLE 9.—*Yields of corn in 1906, oats in 1907, and wheat in 1908 after various rotations at the Indiana station.*

| Plot No. | Previous crop. | Corn. | Oats. | Wheat. |
|---|---|---|---|---|
| 1, 66 | Wheat, clover | 5,000 | 950 | 1,515 |
| 7, 36, 60, 68 | Wheat continuously | 3,938 | 568 | 1,008 |
| 17, 19 | Beans continuously with rye turned under each year | 5,055 | 825 | 925 |
| 21, 27 | Corn continuously | 3,040 | 990 | 1,665 |
| 23, 25 | Orchard grass continuously | 5,900 | 1,160 | 2,095 |
| 34, 72 | Clover continuously | 4,320 | 755 | 1,610 |
| 29, 31 | Fallow continuously | 5,080 | 950 | 1,680 |

The imperfection of the record, especially for the continuous clover plots, makes an interpretation of the figures of doubtful value, but in general the fact seems to stand out that the wheat-cover rotation has maintained the fertility of the land better than continuous wheat culture and perhaps a little better than continuous bean culture with rye as a green manure. If there was clover every year on plots 34 and 72 it would seem as if orchard grass was better than clover, but the lack of records makes it impossible to draw conclusions in regard to this.

MINNESOTA.

At this station four series of rotations were established in 1894. These are outlined in Bulletin 40 (1895), referred to in the annual reports for 1895 and 1896, and are more fully discussed in Bulletin 109 (1908). The review below refers to the latter bulletin. The plots in Series I cover 5-year rotations in which corn, wheat, oats follow in this order with two years of grass or clover between the wheat and oats. The rotations differ only in respect to the meadow crop used. Plots 1, 6, and 11 had clover and timothy; plot 2, brome grass; plot 3, timothy; and plot 4, clover. All plots received 8 tons of manure to the acre on the corn. The rotation for plot 4 is given on page 303 as a 4-year one, and on page 309 as a 5-year one. It is understood that the rotation was a 4-year one.

In Series III wheat is the indicator, being grown continuously in plot 2, and continuously with 6 pounds of red clover seed sown per acre as a catch crop in plot 3; on plots 4 and 5 wheat was rotated with clover, the second crop of clover being plowed under on plot 4 and removed from plot 5. No manure was used on any plot of Series III. The other plots of this series and Series II and IV are of no value for our present study. Unfortunately the value of the results from Series I is practically destroyed because the proposed sequence of crops was not adhered to. The average yield of wheat

was higher from plot 4 (clover) than from any other plot in this series, exceeding that from the next highest plot (timothy and clover) by 3.4 bushels, while the yields from the brome grass and from the timothy plots were between 4 and 5 bushels lower than those from the clover plot. It must be noted, however, that because the proposed course of rotations was not adhered to, one year of wheat preceded meadow and that following this one year of meadow there were seven grain years, three of which were wheat. It would seem, therefore, that the better yield from plot 4 must represent a better soil condition, or be due to some other cause than the roots and stubble of the one year of clover meadow. Plot 3, in which timothy only was used as a meadow crop, yielded nearly as much wheat as the average of plots 1, 6, and 11 (timothy and clover). This plot also yielded 4.3 bushels of oats and 7.7 bushels of corn more than the timothy and clover plots.

In Series III, plots 2 and 3 had wheat every year, but on plot 3 clover was sown with the wheat and turned under as a catch crop. The average annual yield from plot 3 exceeded that from plot 2 by nearly 3 bushels. In a letter dated January 12, 1916, Professor Boss informs the writer that the Minnesota station is still carrying on these two continuous wheat plots and that the addition of 6 pounds of red clover seed to the wheat "has given us an increased yield of wheat of about 2.6 bushels per acre over the entire period." Plots 4 and 5 were treated alike save that on plot 4 the second crop of clover was plowed under and this was removed from plot 5. In spite of this greater amount of green matter turned under the average annual yield of wheat was 2.3 bushels less on plot 4. It would be expected that the greater amount of green matter turned under on plot 4 would have resulted in increased yields. No explanation is forthcoming for the condition recorded.

A large part of this bulletin is devoted to showing that clover in a rotation tends to maintain the nitrogen content of the soil. While the record is not as harmonious as could be wished the evidence for the above mentioned view seems sufficient. The nitrogen content as well as the average annual yields for plots 2 and 3 of Series III are as follows:

| | | Nitrogen present. | |
|---|---|---|---|
| | Yield, bu. | 1895 | 1905. |
| Plot 2, wheat continuously, no clover..... | 18.57 | 0.229 | 0.201 |
| Plot 3, wheat, clover catch crop ......... | 21.8 | 0.223 | 0.253 |

Here not only has plot 3 produced more every year but the nitrogen content has gradually increased while that of plot 2 has decreased. Another series of rotations is recorded in Bulletin 89, but it is not

possible here to separate the influence of the manure added from that of the clover. The rotation plots outyielded those continuously in wheat but this would probably have been the case had there been no clover in the rotation. Other bulletins, as Nos. 53 and 128, treat of the gain and loss of nitrogen and humus under various conditions.

### NEW YORK (CORNELL).

A comparison of the yield of corn and of oats for one year on land that had been in alfalfa for six years with that on a contiguous plot previously in timothy for six years is made in Bulletin 339. On the alfalfa sod corn in 1912 yielded 62 bushels per acre; on the timothy sod, 47 bushels. In 1913 oats were planted, the yield being 26 bushels on the alfalfa land and 27 bushels on the timothy. The growth of corn is said to have been notably greater on the alfalfa than on the timothy sod.

### OHIO.

With the exception of an observation on sweet clover (Bul. 42) and wire-basket experiments described in Bulletin 168, no green manure work has been reported from this station. There is, however, a great mass of literature on rotations and the effect of fertilizers and from the data presented certain conclusions may be drawn. It must be insisted, however, that the evidence on this point is all indirect, the rotations being such that direct comparisons are not possible.

Wheat grown on sweet clover sod in 1891 yielded 26.9 bushels per acre while on adjoining land that had been in corn, oats, or wheat during the preceding four years, the yield was 18.6 bushels (Bul. 42).

The value of having vegetable matter in the soil is brought out in Bulletin 49, where the results from adding phosphates were much better on land rich in organic matter than on that poor in organic matter.

Various rotations covering five or three years have been carried on at the Wooster station and also at some of the substations, and comparisons made with continuous culture. Wheat on both fertilized and unfertilized plots averaged 5.6 bushels per acre better in three years on the rotation plots than on the continuous culture plots (Bul. 53). Corn yields on fertilized plots in continuous culture declined 30 percent in 20 years, while on the fertilized plots in the rotation series the gain in yield was 23 percent (Bul. 282). A 3-year rotation of corn-wheat-clover produced better results than a 5-year one of corn-oats-wheat-clover-timothy (Circ. 120). Wheat, oats, and corn were all grown in continuous culture for 20 years and in 3-year and

5-year rotations for 17 and 20 years respectively, in which the corn followed clover. All three crops yielded best in the rotation series, corn and wheat giving largest yields in the 3-year rotation, the yield of corn being more than twice as large from the 3-year rotation as in continuous culture (Circ. 144). Tobacco grown on clover sod in a 3-year rotation of wheat-clover-tobacco yielded more than 50 percent more than on unfertilized land continuously cropped to tobacco (Bul. 285). It is not possible, however, in any of the above work to separate the benefit, if any, from legumes from that which would accrue merely from the practice of a rotation.

That clover sod may furnish the nitrogen needed for at least the next succeeding crop is shown in Bulletin 182 and in Circulars 40 and 79. In a rotation of potatoes-wheat-clover, some plots received potash and phosphoric acid but no nitrogen while others received varying amounts of nitrogen in addition to potash and phosphoric acid. All plots were on clover sod, and the largest yields were on the plots not receiving nitrogen. In one series (Circ. 40) the yields of wheat following the potatoes were also fully as good on the plots with no extra nitrogen as on those with extra nitrogen. In other cases (Circ. 79) the nitrogen left by the clover appears to have been insufficient for both potato and wheat crops. Soybeans are said to have increased the yield of wheat (Bul. 275, p. 310).

In the wire-basket experiment (Bul. 168), 5 percent of chopped clover was added to the soil, either alone or with lime. Three successive crops of wheat were grown and the rate of transpiration recorded. The green weights were obtained for the first two crops. The first crop was planted 10 days after the clover was added to the soil and both the transpiration rate and the green weights were depressed by the addition of the green manure. A second crop was then grown on the same soil without disturbing it and this showed decided benefit from the green manure, this benefit amounting to about 30 percent. In another wire-basket experiment a similar result was obtained. The first crop was depressed as a result of adding the green manure while the second crop was benefited.

### WISCONSIN.

Potatoes were found to yield more on plots on which a heavy stand of red clover had been turned under than on plots receiving barnyard manure or commercial fertilizers (Bul. 147). The yields of marketable potatoes in bushels per acre were as follows: Barnyard manure, 183.5 bushels; commercial fertilizer, 183 bushels; no fertilizer, 168 bushels; and clover turned under, 234.5 bushels.

SUMMARY.

Wheat and corn have been the chief indicator crops in the northeastern division, with oats and potatoes occupying subordinate positions. With a few exceptions red clover has been used as the legume crop for green manure and for rotation. In Illinois, cowpeas have been used occasionally and there are a few records of trials on alfalfa and on timothy sod.

In most of the Canadian experiments red clover has been used as an annual green manure catch crop, being seeded with wheat and turned under for the next year's wheat. As such, as well as in all the other experiments, red clover proved beneficial to the succeeding crop. In the Canadian experiments, red clover was also shown to have a marked residual value. Even when used as an annual catch crop the effect of turning under clover was frequently noticeable for three successive crops.

At the State stations in this section, there have been few real green manure tests. Minnesota found that a catch crop of clover in wheat was a benefit. Illinois found no benefit from a cowpea catch crop in corn, and in some cases none when cowpeas were grown as a regular summer green manure crop. Most of the work with red clover has been in rotation experiments, and it is difficult to interpret the results with any great degree of clearness. Rotations having clover as one member yielded better than similar rotations without clover, or than continuous cropping, but a part of this result was doubtless due to the better suppression of pests. Even making some allowance for this, however, clover may safely be credited with a beneficial effect upon the yield of corn and wheat in rotation.

That clover and cowpeas were able to furnish the nitrogen for a succeeding crop was shown by both Ohio and Illinois in both pot and field experiments, but the marked residual value of the clover found in Canada was not evident in Ohio.

The value of much of the State work in this section for determining the value of clover is seriously impaired by reason of changed plans or complications in the rotations that make it unsafe to draw positive conclusions.

As a whole it can be said that the results obtained at the State stations in the Ohio and Mississippi valleys have been less striking than those reported from Canada and have often been negative or the evidence has been of doubtful value.

(*To be concluded in the April issue.*)

# THE EFFECT OF DIFFERENT METHODS OF INOCULATION ON THE YIELD AND PROTEIN CONTENT OF ALFALFA AND SWEET CLOVER—2.[1]

A. C. ARNY AND R. W. THATCHER.[2]

In a previous article,[3] we reported the results of the first year's work (on the crop of 1914) on a study of the effect of different methods of inoculation at seeding time upon the yield and composition of alfalfa and sweet clover grown in subsequent years on the treated and adjacent untreated check plots. We have now completed a second year's work, on the crop of 1915. The results of the two seasons' work are, in the main, so concordant and the conclusions to be drawn so plain that we desire to present now the second set of data, together with our conclusions concerning the problems which have been under investigation.

## EFFECT OF DIFFERENT METHODS OF INOCULATION ON THE YIELD AND COMPOSITION OF ALFALFA.

*First Series, Fields E and F; Commercial Culture versus Inoculation with Soil, with and without Liming.*—Full descriptions of the soil conditions, size of plots, methods of seeding, and methods of inoculation used in the series were given in our first paper and need not be repeated here. The only variation from the method of procedure described in that paper was that in 1915 the samples for determination of dry matter and nitrogen content were taken from the green material as it was cut in the field instead of from the air-dried hay. The weights from which the yields of dry matter per acre are calculated were, therefore, the weights of green material as cut instead of those of cured hay.

The plots of Field *E* were seeded during the spring and summer

[1] Contribution from the Minnesota Agricultural Experiment Station. Presented by the junior author at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1916.

[2] The thanks of the authors are due to Messrs. R. A. Thuma and Shinjiro Sato for most of the analytical work from which the data presented in this paper were prepared.

[3] Arny, A. C., and Thatcher, R. W. The effect of different methods of inoculation on the yield and protein content of alfalfa and sweet clover. JOUR. AMER. SOC. AGRON., 7: 172–185. 1915.

of 1912. The crop of 1915, therefore, represents the fourth season's growth, or third harvested crop from these plots. The three cuttings of this crop were made on June 24, July 22, and September 25, respectively. The plots in Field *F* were seeded in the spring of 1913 and the crop here dealt with is the third season's growth, or second crop from these plots, the three cuttings being made on June 22, July 29–30, and September 20.

The total yields of dry matter per acre, the average protein content in the dry matter from each of the three cuttings, and the total yield of protein per acre from each of the three plots which received the same treatment at seeding time and the average of these yields for each kind of treatment are shown in Table 1.

TABLE 1.—*Effect of different methods of inoculation at seeding time (1912 and 1913) on yield and protein content of alfalfa grown in 1915.*
(Field E, Series I, Plots 11–16; Field F, Series III, Plots 18–62.)

| Kind of inoculation. | Plot No. | Dry matter per acre. | Average protein in dry matter. | Protein per acre. |
|---|---|---|---|---|
| | | *Pounds.* | *Percent.* | *Pounds.* |
| None | 11 | 9,632 | 22.34 | 2,152 |
| | 18 | 8,487 | 22.42 | 1,905 |
| | 52 | 8,529 | 20.93 | 1,785 |
| | Average | 8,883 | 21.93 | 1,947 |
| Commercial culture applied to seed | 12 | 9,343 | 22.90 | 2,140 |
| | 24 | 8,656 | 22.52 | 1,949 |
| | 58 | 8,487 | 21.95 | 1,863 |
| | Average | 8,829 | 22.46 | 1,984 |
| Commercial culture applied to soil | 13 | 9,110 | 23.38 | 2,130 |
| | 25 | 8,561 | 23.68 | 2,027 |
| | 59 | 8,171 | 22.22 | 1,816 |
| | Average | 8,614 | 23.10 | 1,991 |
| Soil from alfalfa field | 14 | 9,426 | 22.13 | 2,085 |
| | 26 | 8,226 | 22.71 | 1,868 |
| | 60 | 8,205 | 21.18 | 1,738 |
| | Average | 8,620 | 22.01 | 1,897 |
| Soil from alfalfa field +2 tons limestone per acre | 15 | 9,908 | 22.16 | 2,197 |
| | 27 | 8,218 | 23.45 | 1,928 |
| | 61 | 8,272 | 22.61 | 1,870 |
| | Average | 8,799 | 22.74 | 1,998 |
| None, +2 tons limestone per acre | 16 | 9,402 | 20.85 | 1,964 |
| | 28 | 8,028 | 22.11 | 1,775 |
| | 62 | 8,631 | 21.12 | 1,823 |
| | Average | 8,687 | 21.33 | 1,854 |

The results of the preceding year[4] showed that on the plots in Field *E*, on a well-manured soil, there was no uniform effect of inoculation, either with or without liming, upon the yield or protein content of the crop in the third year after seeding. In Field *F*, how-

[4] *Loc. cit.*, Tables 1, 2, and 6.

ever, on a soil of only medium productivity, in the second year after seeding there was a very considerable increase in the yield of dry matter and a significant increase in the percentage of protein (the combination of these two factors resulting in an increased yield of protein per acre) on those plots which had been inoculated with soil from an old alfalfa field and limed. Both the inoculation alone and the liming alone produced significant increases in growth, while the combination of inoculation and liming produced the largest yields of all. This year's results, on the other hand, do not show any increased yields of either dry matter or protein on the inoculated plots in either of the fields. The variations between plots are not greater than would be expected in duplicate plots in the same field which receive the same treatment.

There are three possible explanations for the coming of these plots to a uniform yielding capacity in the third year after seeding. First, the inoculation may have spread from the plots which were inoculated at seeding time to the untreated check plots in the same series. Second, the heavier draft of the rank-growing inoculated crop upon the plant food in the soil[5] may have reduced the productive capacity of the soil on the inoculated plots to a par with that of the uninoculated plots. And third, the plants on the uninoculated plots may have become so thoroughly well rooted and established by the third season that they are able, without the aid of the bacteria, to make as luxuriant a growth as are those on the inoculated plots.

A comparison of the data presented in Table I with the same data for the crop of 1914 from these same plots indicates very clearly that the first of these explanations is the correct one. The yields of dry matter from all the plots in 1915 were uniformly high, which contradicts the idea that the yields on the inoculated plots have come down to the basis of lack of inoculation. Furthermore, it is clear that the percentage of nitrogen (protein) in the crop from the uninoculated plots has increased up to the average of that for the inoculated plots, which in itself is a good indication that the plants on the plots which were not inoculated at seeding time are now as well supplied with the nitrogen-fixing bacteria as are those on the inoculated plots.

A search of the literature dealing with alfalfa inoculation experiments has failed to give any other evidence bearing upon this problem. Hutton[6] reports yields of alfalfa in 1910 at the Lacombe Farm, on

[5] *Loc. cit.*, Table II.

[6] Hutton, G. H. Comparing inoculated soil with culture as a means of inoculating for alfalfa. Canada Expt. Farm Rpt. 1911, p. 496.

plots seeded in the spring of 1909 with different methods of inoculation, but no yields in subsequent years, on these same plots, have been reported. Other experimenters report "success" or "improvement" in obtaining a stand of alfalfa during the first season after the experimental inoculation.

*Second Series, Quinn Farm, Inoculation of Alfalfa by Transfer of Soil from Sweet Clover and Alfalfa Fields.*—These plots were seeded in April, 1913, on soil which had never grown alfalfa, nor had this crop ever been grown within half a mile of the field. The crop of 1914 showed a very large gain in yield of dry matter per acre[7] and in percentage of protein in the dry matter[8] from those plots which had been inoculated at seeding time, soil from an alfalfa field and from a sweet clover field being equally efficient in producing both these results.

The yields of dry matter and protein content of the crops from these same plots in 1915, from the three cuttings made on June 16–17, August 7, and September 24, respectively, are shown in Table 2.

TABLE 2.—*Effect of inoculation of alfalfa when sown in 1914 with soil from sweet clover field and from alfalfa field on the yield and protein content of the crop in 1915.*

(Quinn Farm.)

| Plot No. | Kind of inoculation. | Dry matter per acre. | Protein in dry matter. | Protein per acre. |
|---|---|---|---|---|
| | | *Pounds.* | *Percent.* | *Pounds.* |
| 12 | None | 3,129 | 19.87 | 1,136 |
| 13 | With sweet clover soil | 3,824 | 20.97 | 1,366 |
| 14 | None | 3,615 | 19.84 | 1,295 |
| 17 | With alfalfa soil | 4,423 | 21.61 | 1,604 |
| 20 | None | 3,301 | 19.45 | 1,320 |

The results presented in Table 2 clearly show that the effect of inoculation at seeding time (in 1913) is much less in the crop of 1915 than in that of 1914. There is, however, a significant increase in yield of dry matter and in the percentage of protein in the dry matter on the inoculated plots, as compared with the adjacent uninoculated ones, even in this third year after seeding. It appears from these results, as well as from those of the preceding year on plots which had been inoculated two and three years previously, that the effect of inoculation at seeding time upon the chemical composition of the resultant crops is very marked in the first crop (second season's growth), comparatively slight but still noticeable in the second crop

[7] Arny, A. C., and Thatcher, R. W. *Loc. cit.*, p. 177, Table 3.

[8] *Loc. cit.*, p. 178, Table 4.

(third season's growth) and disappears entirely in subsequent crops. This is undoubtedly due to the spread of the inoculating bacteria from the inoculated plots to adjacent uninoculated ones. It appears that, under the conditions at University Farm, this takes place to a very considerable extent during the second season's growth and that by the close of the third season the uninoculated plots in any given series are sufficiently supplied with bacteria so that subsequent crops are uniform in yield and protein content, at least so far as inoculation is concerned. There seems to be no need, therefore, to carry any studies of the effect of inoculation beyond the second season's growth, under our conditions. On the other hand, if further studies of this kind are projected, they must provide for comparison plots located at such distances apart that there can be no possibility of transfer of inoculation from one plot to another.

The difference in yield in 1915 between the plots inoculated with alfalfa soil and with sweet clover soil is probably due to other causes than the difference in character of the inoculating material, as results in other fields clearly contradict the assumption that inoculation with alfalfa bacteria is more effective than that with sweet clover bacteria.

### Effect of Inoculation on Yield and Composition of Tops and Roots of Sweet Clover and Alfalfa.

The results of the first year's study of this problem gave some very conclusive evidence concerning the effect of inoculation upon the total yield of dry matter per plant and upon the ratio of tops to roots in both alfalfa and sweet clover plants, but left some uncertainty as to the effect of the inoculation upon the chemical composition of the different parts of the plants, especially with regard to certain of the mineral constituents in the roots. It was thought that this might be due in part to the difficulty which was experienced in getting the fine fibrous roots wholly free from soil particles, and in part to the fact that the small amount of material which was available did not permit as large a number of analytical determinations as was desired. On this account, we decided to repeat the experiments. The desired inoculated and uninoculated check material was available and, with the experience of the preceding year as a guide, much more satisfactory sampling of the plant growths was obtained. This year's results present very convincing evidence on all the points in question and the data are presented with the conclusions which we have drawn from them.

The method of measuring the sample square-yard areas and of securing the entire growth of tops and roots was essentially the same

as that described in our former paper.[9] With added experience, however, it was found possible to collect more completely the fibrous root growth of the plants and to free this almost entirely from soil particles, so that the samples as received at the laboratory were very good representatives of the crops as they grew in the field.

In the field from which the sample square yards of sweet clover were taken, there were available plots which had been inoculated at seeding time, other plots which had been both inoculated and limed, and untreated check plots. Accordingly, three typical square yards in each of these three kinds of material were harvested, weighed, and analyzed. The number of plants and the total yield of tops and roots (both green weight and dry matter) for each of these nine square-yard tracts and the average total yield of dry matter per square yard for each of the three treatments are shown in Table 3.

TABLE 3.—*Effect of inoculation on growth of tops and roots of sweet clover and of alfalfa, as shown by the green and dry weights per square yard and the dry matter per plant (all weights in grams).*

SWEET CLOVER.

| Treatment. | Sq. Yd. No. | No. of plants. | Green weight. | | Total dry matter. | | Dry matter per plant. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tops. | Roots. | Tops. | Roots. | Tops. | Roots. | Total. | Average for plot. |
| Inoculated and limed. | 1 | 70 | 2,062.5 | 336.4 | 534.5 | 88.0 | 7.636 | 1.257 | 8.893 | 6.796 |
| | 2 | 82 | 1,922.5 | 291.5 | 456.5 | 70.3 | 5.567 | 0.857 | 6.424 | |
| | 3 | 108 | 2,003.5 | 271.0 | 484.5 | 63.2 | 4.486 | 0.585 | 5.071 | |
| Inoculated only...... | 4 | 70 | 1,216.7 | 228.1 | 301.7 | 60.1 | 4.310 | 0.859 | 5.169 | 5.825 |
| | 5 | 57 | 1,204.0 | 194.5 | 273.0 | 45.1 | 4.790 | 0.791 | 5.581 | |
| | 6 | 72 | 1,828.0 | 267.5 | 416.0 | 68.1 | 5.778 | 0.946 | 6.724 | |
| None.............. | 7 | 80 | 585.0 | 134.7 | 148.0 | 36.0 | 1.850 | 0.450 | 2.300 | 1.799 |
| | 8 | 80 | 406.3 | 103.8 | 97.3 | 26.4 | 1.216 | 0.330 | 1.546 | |
| | 9 | 79 | 417.5 | 95.0 | 100.5 | 22.0 | 1.272 | 0.279 | 1.551 | |

ALFALFA.

| Treatment. | Sq. Yd. No. | No. of plants. | Green weight. Tops. | Green weight. Roots. | Total dry matter. Tops. | Total dry matter. Roots. | Dry matter per plant. Tops. | Roots. | Total. | Average for plot. |
|---|---|---|---|---|---|---|---|---|---|---|
| Inoculated.......... | 4 | 139 | 1,384 | 363 | 347.4 | 107.0 | 2.500 | 0.769 | 3.269 | 2.789 |
| | 5 | 288 | 1,789 | 667 | 469.4 | 193.7 | 1.629 | 0.673 | 2.302 | |
| | 6 | 169 | 1,435 | 461 | 348.1 | 124.1 | 2.060 | 0.735 | 2.795 | |
| Not inoculated...... | 1 | 157 | 317 | 188 | 86.0 | 60.0 | 0.548 | 0.382 | 0.930 | 0.786 |
| | 2 | 203 | 213 | 124 | 57.8 | 40.1 | 0.285 | 0.197 | 0.482 | |
| | 3 | 140 | 281 | 147 | 80.3 | 52.1 | 0.574 | 0.372 | 0.946 | |

These data show the same general effects from the inoculation as were found in the first year. The yields of dry matter per plant and per plot were greater on the inoculated and limed plot than on the plot which was inoculated but not limed, and on each of these the yields were more than three times as great as on the uninoculated

[9] *Loc. cit.*, p. 180–182.

plot. This shows a very remarkable increase in growth in the first crop (second season's growth) as a result of the treatment at seeding time.

Table 3 also gives data concerning the yields from the three square yards each of inoculated and uninoculated alfalfa. Here again the effect of the inoculation at seeding time upon the amount of crop produced the following season is very marked, the average yield of dry matter from the three inoculated square yards being almost four times as great as that from the uninoculated plots.

As would be expected, the yield of dry matter per plant on the different square-yard plots varies inversely with the number of plants on each particular plot. There seems to be no exact correlation between the yield of dry matter per plant or per plot and the number of plants on each particular plot. In general, it appears that on the inoculated plots the thicker stand (i. e., larger number of plants per square yard) gave heavier yields of total dry matter, while on the uninoculated plots the thinner stands usually produced the greater growths of dry matter. There are several exceptions to this general rule, however, in the results of both seasons.

The same effect of inoculation in increasing the proportion of tops to roots in both sweet clover and alfalfa that was noticed in the former work appeared in the data shown in Table 3. The ratios of dry matter in the tops to that in the roots is presented in Table 4.

TABLE 4.—*Effect of inoculation on ratio of tops to roots in sweet clover and alfalfa.*

| Crop. | Treatment. | Ratio of dry matter in tops to roots. | | | |
|---|---|---|---|---|---|
| | | Square yard No. | | | Average. |
| | | 1 | 2 | 3 | |
| Sweet clover.... | Inoculated and limed..... | 6.07:1 | 6.49:1 | 7.67:1 | 6.74:1 |
| | Inoculated only......... | 5.02:1 | 6.05:1 | 6.11:1 | 5.73:1 |
| | None.................. | 4.11:1 | 3.68:1 | 4.57:1 | 4.09:1 |
| Alfalfa......... | Inoculated............. | 3.19:1 | 2.37:1 | 2.80:1 | 2.79:1 |
| | Not inoculated.......... | 1.43:1 | 1.44:1 | 1.54:1 | 1.48:1 |

The data in Table 4 confirm those of the preceding year. In every individual case, of the total of 27 square yards which were investigated in the two seasons, the ratio of tops to roots was significantly greater in the plants from the inoculated plots than in those from plots which had not been inoculated. The same general effect is to be observed in the data presented by Fred and Graul in their recent paper[10] on the effect of soluble nitrogenous salts on nodule forma-

[10] Fred, E. B., and Graul, E. J. The effect of soluble nitrogenous salts on nodule formation. JOUR. AMER. SOC. AGRON., 8: 316–328. 1916.

tion. In nearly every case reported by them the ratio of dry matter in tops to that in roots is greater in the pot where inoculation was successful (as indicated by the formation of numerous nodules) than in the uninoculated pot which received otherwise the same treatment, this being true of both the alfalfa and the vetch crops. Their pot tests show occasional exceptions to the general rule, whereas our square-yard field tests exhibit no exceptions. The ratios vary with different square yards, as might be expected, but in no single case is the ratio of tops to roots as high in the uninoculated material as in that which received inoculation.

The obvious conclusion from these results is that the effect of inoculation in increasing the yield of harvestable forage is due not only to an increase in the total dry matter per plant (as shown in Tables 4 and 5), but also to the deposition of a larger proportion of the material elaborated by each plant in the above-ground portion of it.

The carefully prepared samples from these square-yard plots afforded excellent material for a continuation of the study of the effect of inoculation upon the quantity of plant-food constituents removed from the soil by these crops, which was begun last year. The samples were prepared and analyzed in the same way as described in the former paper, with the single exception that the percentage of calcium in the composite sample from each plot was determined, in addition to those previously reported. The results of the analyses are shown in Table 5.

These data clearly show the following effects of the inoculation upon the percentages of plant food constituents in the crop:

1. The percentage of ash in the dry matter is decreased in the tops and not affected or very slightly increased in the roots.

2. The percentage of nitrogen is increased in both the tops and the roots.

3. The percentage of phosphorus is lower in both the tops and the roots of the inoculated sweet clover, but in the alfalfa there is no significant effect of the inoculation, the percentage of $P_2O_5$ being slightly lower in the tops and slightly higher in the roots of the inoculated plants.

4. The percentage of potassium is higher in both the tops and the roots of the inoculated sweet clover, and lower in both the tops and the roots of the inoculated alfalfa.

5. The percentage of lime in the dry matter does not appear to be significantly affected by inoculation. In the sweet clover samples, the

lime content of the inoculated and uninoculated plants is practically identical, while the plants from the plots which were limed at seeding time contain a lower percentage of calcium oxide than those from the unlimed plots. In the alfalfa samples, the percentage of lime is lower in the tops and higher in the roots of the uninoculated plants.

TABLE 5.—*Effect of inoculation on plant-food constituents in tops and roots of sweet clover and alfalfa.*

SWEET CLOVER.

| Treatment. | Sq. Yd. No. | Plant-food constituents (calculated as percentages of the dry matter.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tops. | | | | | Roots. | | | | |
| | | Ash. | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. | Ash. | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. |
| Inoculated and limed | 1 | 6.81 | 2.48 | | | | 4.54 | 2.03 | | | |
| | 2 | 6.82 | 2.54 | 0.82 | 2.49 | 0.45 | 5.39 | 2.10 | 0.93 | 1.89 | 0.07 |
| | 3 | 7.15 | 2.47 | | | | 5.15 | 1.98 | | | |
| Inoculated only | 4 | 6.21 | 2.30 | | | | 5.58 | 1.96 | | | |
| | 5 | 6.97 | 2.33 | 0.69 | 2.53 | 0.58 | 5.43 | 2.18 | 0.91 | 1.80 | 0.10 |
| | 6 | 6.41 | 2.24 | | | | 4.95 | 1.89 | | | |
| None | 7 | 7.35 | 1.31 | | | | 4.62 | 0.89 | | | |
| | 8 | 7.77 | 1.44 | 1.12 | 1.78 | 0.60 | 4.93 | 0.95 | 1.02 | 1.68 | 0.10 |
| | 9 | 7.49 | 1.35 | | | | 4.83 | 0.82 | | | |

ALFALFA.

| Treatment. | Sq. Yd. No. | Ash. | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. | Ash. | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inoculated | 4 | 8.33 | 2.59 | | | | 3.98 | 1.94 | | | |
| | 5 | 7.74 | 2.36 | .77 | 1.12 | 1.69 | 4.58 | 2.20 | .82 | .65 | .19 |
| | 6 | 8.32 | 2.74 | | | | 4.45 | 2.29 | | | |
| Not inoculated | 1 | 9.65 | 1.56 | | | | 4.09 | .73 | | | |
| | 2 | 10.52 | 1.59 | .89 | 1.74 | 2.17 | 4.74 | .75 | .70 | .88 | .13 |
| | 3 | 10.18 | 1.37 | | | | 3.50 | .65 | | | |

The percentages of these plant-food constituents in the dry matter are, of course, more or less dependent upon the stimulating effect of the inoculation upon the growth of the plants. For example, an increased production of protein in the plant results in a diminished percentage of all these plant-food constituents except nitrogen, while a stimulation of carbohydrate production would decrease the percentage of all plant-food elements in the dry matter. For this reason, a better basis of study of the resultant effect of inoculation upon the ability of the plant to draw upon these plant food elements in the soil is the total amount of these elements found in the dry matter from each identical area. These computations have therefore been made, and the resulting data are presented in Table 6.

These data clearly show that inoculation, resulting in increased growth, gives to the crop a very largely increased power to draw upon the plant-food constituents of the soil. The effect does not seem to

be simply the result of increased growth processes, since it is not uniform for the several mineral elements, but is generally greater in the case of potassium than of the other elements which were determined in these analyses. The figures for total ash in the dry matter in both seasons indicate that the inoculated plants are able to elaborate a greater amount of organic material from a given amount of mineral constituents than are the uninoculated ones. There seems, therefore, to be some physiological effect upon the growth of the plants, due to the presence of nodule-forming bacteria on their roots, other than a simple increase in nitrogen supply to the growing plants.

TABLE 6.—*Effect of inoculation upon quantity of plant food constituents in crops of sweet clover and alfalfa.*

(Average of three square yard plots in each case.)

| Crop and treatment. | Part of plants. | Plant-food constituents present in crop. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Grams per square yard. | | | | Pounds per acre. | | | |
| | | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. | Nitrogen. | $P_2O_5$. | $K_2O$. | CaO. |
| Sweet clover: | | | | | | | | | |
| Inoculated and limed.. | Tops | 12.21 | 4.03 | 12.25 | 2.21 | | | | |
| | Roots | 1.50 | 0.68 | 1.39 | 0.05 | | | | |
| | Whole plant | 13.71 | 4.71 | 13.64 | 2.26 | 153 | 52 | 152 | 25 |
| Inoculated only...... | Tops | 7.54 | 2.28 | 8.35 | 1.91 | | | | |
| | Roots | 1.12 | 0.53 | 1.04 | 0.06 | | | | |
| | Whole plant | 8.66 | 2.81 | 9.39 | 1.97 | 96 | 31 | 105 | 22 |
| None............... | Tops | 1.56 | 1.29 | 2.05 | 0.69 | | | | |
| | Roots | 0.25 | 0.29 | 0.47 | 0.03 | | | | |
| | Whole plant | 1.81 | 1.58 | 2.52 | 0.72 | 20 | 18 | 29 | 8 |
| Alfalfa: | | | | | | | | | |
| Inoculated.......... | Tops | 9.87 | 2.99 | 4.35 | 7.16 | | | | |
| | Roots | 3.06 | 1.16 | 0.92 | 0.27 | | | | |
| | Whole plant | 12.93 | 4.15 | 5.27 | 7.43 | 134 | 46 | 59 | 83 |
| Not inoculated....... | Tops | 1.12 | 0.66 | 1.30 | 1.62 | | | | |
| | Roots | 0.35 | 0.36 | 0.45 | 0.07 | | | | |
| | Whole plant | 1.47 | 1.02 | 1.75 | 1.69 | 16 | 11 | 19 | 19 |

## SUMMARY AND CONCLUSIONS.

Studies have been carried on in two successive seasons (1914 and 1915) of the effect of inoculation by various methods at seeding time upon the yield and composition of the crops grown in the second, third, and fourth seasons thereafter, on three different fields of the University Farm, St. Paul, Minn.

In this and in the preceding paper of the same title, data are presented which show (*a*) the yield and protein content of the three successive cuttings in each of the two years from fourteen inoculated plots and nine adjacent uninoculated check plots of alfalfa; (*b*) the

yield and protein content of one year's crop from two inoculated and three uninoculated sweet clover plots; and (*c*) two successive seasons' analyses of the tops and roots from 3 square yards each of inoculated and uninoculated alfalfa and sweet clover.

These data point clearly to the following conclusions with reference to the effect of inoculation upon the yield and composition of these leguminous crops when grown on soils of the type represented by those on University Farm.

1. Inoculation at seeding time produces a very large increase in yield of dry matter per acre and in the percentage of protein in the dry matter in the second season thereafter (first harvestable crop), as compared with the yield and composition of the crop from adjacent uninoculated plots. In the next season's growth (second harvestable crop), the differences are much less noticeable and they practically disappear in the following year, by reason of the rapid spread of the inoculating bacteria to the uninoculated plots.

2. Inoculation of either alfalfa or sweet clover with soil from fields on which either alfalfa or sweet clover has been growing successfully is equally efficient in producing these effects.

3. Inoculation with soil is generally more efficient in these respects than inoculation with the commercial cultures which were used in our experiments.

4. Liming the soil at seeding time (2 tons ground limestone per acre) slightly intensifies the above-mentioned effects of inoculation.

5. One effect of inoculation is to give to the inoculated plants an increased capacity to utilize mineral soil nutrients, the increased growth resulting in the removal from the soil of very much larger amounts of potassium, phosphorus, and calcium.

6. A second effect of inoculation is to make it possible for the inoculated plants to elaborate a somewhat larger amount of dry matter from a given amount of mineral plant food elements.

Minnesota Agricultural Experiment Station,
University Farm, St. Paul, Minn.

# A NEW METHOD FOR HARVESTING SMALL GRAIN AND GRASS PLOTS.

A. G. McCall.

In varietal testing and in soil fertility plot work one of the most serious difficulties encountered is that of obtaining accurate yields of the several plots included in the test. While the harvesting and weighing of the entire product of the plot should, theoretically, be most satisfactory, this method is attended by certain difficulties that make it practically impossible to get accurate results. The lodging of the grain, the depredations of birds and mice, and losses incident to weathering are some of the more serious difficulties met when the entire plot is harvested. When plot work is being conducted in several sections of the State another difficulty is encountered, namely, the supplying of suitable machinery to thrash the grain from the small plots separately.

These difficulties have been overcome to a certain extent by harvesting a number of small areas from each plot and calculating from these the yield of the entire plot. The chief objections to this method are (1) the inconvenience encountered in laying off the small areas, and (2) the difficulty of obtaining representative areas.

To overcome the first objection the writer has recently constructed, for the work at the Maryland Agricultural Experiment Station, a small apparatus to be used in harvesting accurate areas of grass, wheat, or other small grains. The essential details of this harvester are shown in figure 7. For the harvesting of grain that has been seeded in drills only the grain board (*A*) and the two spears (*B, B'*) are used, the method of procedure being as follows: With the spears withdrawn the grain board is placed in position parallel and close to the outside drill row of the plot and fastened in this position by means of two short spears (not shown in the drawing) which project into the soil from the lower edge of the board. The long spears, *B, B'*, are now thrust through the metal sleeves at *C, C'* and into the plot, thus marking off two parallel lines at right angles to the drill rows. The distance between these spears should be such that 4 or 5 drill rows thus marked off will give an even fraction of an acre.

For grass and for grains that are seeded broadcast the manipulation is essentially the same as for the drilled grain except that, since

there is no drill row, the fourth side of the area must be defined by the use of a third spear, which must be parallel to the grain board. To

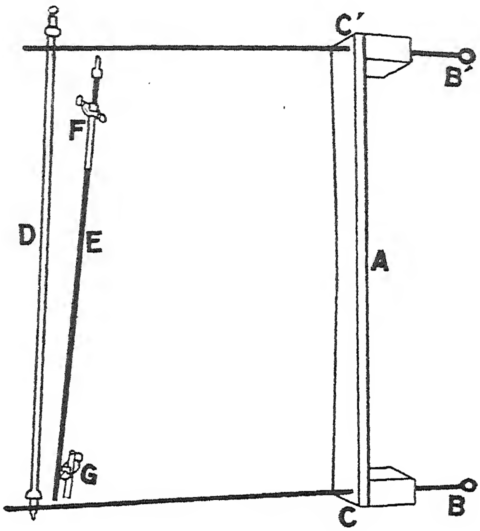


FIG. 7. Frame for use in harvesting small blocks from grain and grass plots.

accomplish this the two spears, *B, B'*, are securely clamped in position by means of the bar *D*, after which the sleeve *F* is clamped to the spear *B'* near the tip and at a definite distance from the board *A*. The third spear, *E*, is now thrust through the sleeve *F* until it engages the sleeve *G* which is clamped to spear *B* directly opposite the sleeve

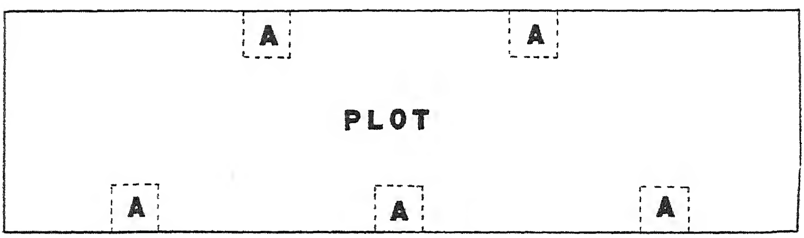


FIG. 8. Diagram showing location of blocks (A) in grain or grass plots in order to obtain representative samples.

*F*, thus marking off the fourth side of the small area that is to be harvested. Having defined the boundaries it only remains to cut the grain or the grass included within the spears.

By the aid of this apparatus it is possible to measure with great

accuracy an area of small dimensions even though the grain or grass is badly lodged and tangled. It is proposed to harvest 5 of these small areas of one five-thousandth of an acre each, or a total of one one-thousandth of an acre, from each large plot and to thrash the grain with a small thrashing outfit. The locations of these small areas are shown in figure 8. The small bundles of grain are taken to the barn the same day they are harvested, suspended on drying racks until thrashed, and weighed when properly cured. Plots in remote parts of the State will be harvested in a similar manner and the bundles of grain shipped to the central station in canvas bags.

A preliminary trial of the apparatus on wheat and on timothy plots gave results that check up quite satisfactorily with the records obtained by harvesting and thrashing the entire plots.

This brief account is presented with the hope that some members of the American Society of Agronomy will be sufficiently interested to construct a similar apparatus, use it during the next harvest period, and report their experience at the next meeting of the Society.

Maryland Agricultural Experiment Station,
College Park, Maryland.

# AGRONOMIC AFFAIRS.

## MEMBERSHIP DUES.

All those whose membership dues for 1916 in the American Society of Agronomy are not paid by March 31 will automatically lapse. The names of lapsed members will be printed in the May number of the JOURNAL. The few whose dues are still unpaid are urged to remit promptly in order that they may be reinstated before that time.

By reason of the change in the by-laws of the Society effected at the last annual meeting, those whose dues for 1917 are not paid by April 1 will receive no more numbers of the JOURNAL until they remit. This provision was made in order to comply with the postal laws and also to safeguard those members whose dues are paid promptly. One who delays the payment of annual dues until several notices have been sent him entails unnecessary expense on the Society and causes the Treasurer needless work. One who does not pay at all should not, as has been the case in the past, receive the JOURNAL for more than a year without cost. All members are urged to remit their dues for 1917 to the Treasurer so that there will be no delay in the delivery of the JOURNAL to them.

## MEMBERSHIP CHANGES.

The membership of the Society as reported in the January JOURNAL was 618. Since that time 31 new members have been added and 7 members have resigned, a net gain of 24 and a present membership of 642. The names and addresses of the new members, the names of those who have resigned, and such changes of address as have come to the notice of the Secretary follow.

### NEW MEMBERS.

AGEE, JOHN H., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
BELL, N. ERIC, Agriculture & Industries Dept., Montgomery, Ala.
BINFORD, E. E., Substation No. 1, Beeville, Tex.
BRANDON, JOSEPH F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
BRYANT, ROY, 111 West Street, Stillwater, Okla.
CLEMMER, H. J., Woodward Field Station, Woodward, Okla.
COE, H. S., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
CONREY, G. W., Soils Building, University of Wisconsin, Madison, Wis.

DAVISSON, BERT S., Ohio Agr. Expt. Sta., Wooster, Ohio.
DEETER, E. B., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
DOWNS, E. E., Michigan Agr. College, East Lansing, Mich.
FLETCHER, C. C., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
FLETCHER, O. S., Ellensburg High School, Ellensburg, Wash.
FURRY, R. L., Ferguson Seed Co., Sherman, Tex.
HOTCHKISS, W. S., Substation No. 2, Troup, Tex.
HUELSKEMPER, EDWARD H., 411 Terry Street, Longmont, Colo.
HURST, J. B., 111 Knoblock Street, Stillwater, Okla.
JARRELL, J. F., Expt. Dept., Great Western Sugar Co., Longmont, Colo.
KUSKA, J. B., Colby Substation, Colby, Kans.
MCILVAINE, T. C., W. Va. Agr. Expt. Sta., Morgantown, W. Va.
MCNESS, GEO. T., Nacogdoches Substation, Nacogdoches, Tex.
MUNDELL, J. E., Big Springs Expt. Farm, Big Springs, Tex.
PATE, W. F., N. C. Agr. Expt. Sta., West Raleigh, N. C.
REED, EVERETT P., N. Y. Agr. Expt. Sta., Geneva, N. Y.
SCHUER, HENRY W., 296 Chestnut St., Chillicothe, Ohio.
SHINN, E. H., 238 Main Street, Stillwater, Okla.
SMITH, J. B., Dept. of Farm Crops, College of Agr., Columbia, Mo.
TILLMAN, B. W., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
TRUE, RODNEY H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
WARD, WYLIE R., University Farm, Lincoln, Nebr.
WOO, MOI LEE, Spreckels, Cal.

## MEMBERS RESIGNED.

BUELL, T. W.
CORY, VICTOR L.
HOLTZ, HENRY F.
LECLAIR, C. A.
MCMURDO, GEO. A.
NUCKOLS, S. B.
ORTON, W. A.

## ADDRESSES CHANGED.

DORSEY, HENRY, 306 Stewart Ave., Ithaca, N. Y.
GARLAND, JOHN J., Holmes-Letterman Seed Co., Canton, Ohio.
HENDRY, GEO. W., University Farm, Davis, Cal.
HERSHBERGER, JOS. P., jr., 1835 Indianola St., Columbus, Ohio.
HILL, W. H., Laboratory Inland Rev. Dept., 317 Queen St., Ottawa, Ont.
MARTIN, THOS. L., Castle Dale, Utah.
PHILLIPS, THOS. G., College of Agriculture, Columbus, Ohio.
TUTTLE, H. FOLEY, Dept. Soil Physics, University of Illinois, Urbana, Ill.
WELCH, J. S., Paradise, Utah.

## NOTES AND NEWS.

A. C. Hartenbower has resigned as agronomist in charge of the Guam station and has returned to the continental United States. He has been succeeded in Guam by C. W. Edwards, formerly engaged in agricultural work in the Philippines.

R. B. Lowry succeeded J. C. Pridmore as associate professor of agronomy in the University of Tennessee on February 1. Mr. Pridmore's resignation to enter commercial work was previously noted.

George E. Vincent, for the past several years president of the University of Minnesota, has resigned to become president of the Rockefeller Foundation and has entered on his duties in the latter position. Marion L. Burton, president of Smith College, has been elected to succeed him in Minnesota and has accepted the position.

J. S. Welch, superintendent of the Gooding (Idaho) substation, has resigned and has sailed for New Zealand, where he will teach agriculture in the Maori agricultural college.

Albert F. Woods, dean of the Minnesota college of agriculture and director of the experiment station since 1910, has accepted the presidency of the Maryland State College and will begin his new duties on July 1. His new position entails the supervision of all the agricultural activities of the State.

Several administrative changes have been effected in the Federal Office of Dry-Land Agriculture. John S. Cole will have general charge of field stations, assisted by John M. Stephens in the northern, O. J. Grace in the central, and E. F. Chilcott in the southern Great Plains. Messrs. Stephens, Grace, and Chilcott will retain the superintendencies of the Judith Basin (Mont.), Akron (Colo.), and Woodward (Okla.) field stations, respectively. W. E. Lyness has been transferred from the Akron to the Archer, Wyo., station, and has been succeeded at Akron by Jos. F. Brandon of the University of Illinois. Albert Osenbrug has been assigned to the Scottsbluff, Nebr., station, and H. J. Clemmer to the station at Woodward, Okla.

J. A. Holden has succeeded Fritz Knorr as superintendent of the Scottsbluff, Nebr., experiment farm of the Office of Western Irrigation Agriculture. Mr. Knorr is now engaged in farming in northern Alabama.

## Local Sections.

The fifeenth regular meeting of the Washington (D. C.) section was held at the Cosmos Club, February 9, 1917. The program consisted of a paper entitled "Some Features of Soil Classification," by Dr. C. F. Marbut, in charge of soil survey in the U. S. Department of Agriculture. Dr. Marbut defined soil from the standpoints of the geologist, pedologist, and agronomist, stating that to the latter a soil is anything in which plants grow. He showed that soils derived from the same or similar rocks may vary widely, while similar soils may be derived from very different rocks, illustrating the futility of a geologic classification of soils. He then discussed at length the several soil belts which extend around the world, as pointed out in a Russian work on soils published in 1914 and which is still extremely rare in this country. According to the Russian scientists, there is a great belt of tundra in the north, the progression from north to south being through belts of gray forest and black prairie soils into the yellow and red soils of the semitropical and tropical countries.

The sixteenth regular meeting of the Washington section was held on March 1. The program included papers on "Experiments on the Effect of Fall Irrigation on Crop Yields," by F. D. Farrell; "Progression of the Wheat Harvest from South to North in the Great Plains," by Joseph F. Brandon; and a report of recent studies in evaporation and transpiration, by L. J. Briggs and H. L. Shantz.

The first regular meeting of the Columbus (Ohio) section during 1917 was held February 1, during Farmers' Week. Dr. E. R. Allen of the Ohio station presented an interesting paper on "The Attack on the Problem of Soil Biology." The meeting was so enjoyable and profitable that it was decided to continue the practice of holding a meeting of the section during Farmers' Week, making it the one big affair of the year.

The following papers have been presented before the South Dakota section at Brookings since January 1:

On January 12, "Wheat Rust," by A. N. Hume; on February 2, "Transpiration of Sweet Clover in Different Soil Types," by Howard Loomis; and on March 1, "Cooperative Cereal Experiments at Highmore" and "Sorghum Culture in South Dakota," by J. D. Morrison and George Winwright.

# JOURNAL

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## THE EFFECT OF SODIUM NITRATE APPLIED AT DIFFERENT STAGES OF GROWTH ON THE YIELD, COMPOSITION, AND QUALITY OF WHEAT.[1]


J. DAVIDSON AND J. A. LE CLERC.


### INTRODUCTION.

The work of Le Clerc and Leavitt[2] showed that the variation in nitrogen content of wheat is independent of the original nitrogen content of the seed used. This conclusion has since been corroborated by data which have not yet been published with reference to wheat and other cereals. The work of Shaw and Walters[3] and also that of Le Clerc and Yoder[4] further showed that the soil is a minor factor in accounting for the variation in the nitrogen content of wheat. The logical conclusion of these experiments is that the principal factor producing variations in the nitrogen content of wheat within the limits of these experiments is climate. Climate, however, is a complex of a number of factors, as rainfall, sunshine, elevation, minimum and maximum temperature, etc. It remains to be found

[1] Contribution from the Plant Chemical Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture. Presented at the ninth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1916.

[2] Le Clerc, J. A., and Leavitt, Sherman. Trilocal experiments on the influence of environment on the composition of wheat. U. S. Dept. Agr., Bur. Chem. Bul. 128, 18 p. 1910.

[3] Shaw, Geo. W., and Walters, E. C. A progress report upon soil and climatic factors influencing the composition of wheat. Cal. Agr. Expt. Sta. Bul. 216, p. 549–574. 1911.

[4] Le Clerc, J. A., and Yoder, P. A. Environmental influences on the physical and chemical characteristics of wheat. U. S. Dept. Agr., Jour. Agr. Research, v. 1, no. 4, p. 275–291. 1914.

out which factor or which combination of factors composing climate is responsible for these variations. It remains further to be determined whether the action of climate is direct, affecting the metabolism of the plant, or if it is indirect, affecting the amount of available plant food in the soil. The work reported here was undertaken as the first step in answering these questions. It was thought that perhaps climate was responsible for the variation in the available nitrates at different stages of growth, and it was therefore deemed advisable to see what would be the effect of applying sodium nitrate at different stages of growth.

## Plan of Experiments.

*Size of Plot.*—There has been much discussion in agronomic literature with reference to size of plot for field experiments. The tenth-acre plot is commonly accepted. The reason for using such large plots is to overcome the lack of uniformity in the soil and to allow for variation in the vitality of the seed used. In the present experiments there has been a conspicuous deviation in the method of laying out and in the size of the plots from the general practice. The plots were laid out after the crop was up. Areas showing uniform growth were selected and therefore it was possible to limit the plots to 1 square rod each. The results, as will be shown further, have proved quite satisfactory, and would no doubt have been much more satisfactory if the land had been more carefully prepared and drilled.

*Method of Applying Fertilizer.*—The sodium nitrate was used at the rate of 2 pounds per plot, equivalent to 320 pounds per acre. It was applied in one period, two periods, and three periods. The periods chosen were:

(1) When the crop was about 2 inches high.
(2) Time of heading.
(3) Milk stage.

In order to assure the availability of the fertilizer at the particular stages of growth, the nitrate was applied in solution. The concentration of the solution was 1 to 100 in all cases.

To check the advisability of applying the fertilizer in solution in the future, parallel plots were prepared to which the solid fertilizer was applied. These plots received the same amount of water as the plots to which the fertilizer was applied in solution, except that the water was added the day before the application of the nitrate. The plots which received the fertilizer in two or three periods also received the same amount of water as those plots which received the

fertilizer in one period. The additional water above the amount required to make up the proper concentration was added the previous day. Therefore, all these plots received the same amount of water at each of the three different stages of growth.

To check the effect of water a series of plots was prepared to which the fertilizer was applied in solid state and to which no water was added. An additional series of plots was prepared to which sodium nitrate and potassium chloride were applied, and also one to which potassium chloride alone was added. These series were planned in order to see whether the relation between nitrates and potash on the one hand and the quality and composition of wheat on the other found by Headden[5] would hold good under these conditions. The experiment was carried on in duplicate series. The details of the treatment which was given the individual plots are presented in the following pages. The experiment was carried out in 1916 on the Kentucky Agricultural Experiment Station Farm at Lexington, Ky.[6]

TREATMENT OF INDIVIDUAL PLOTS AT DIFFERENT STAGES OF GROWTH.

| Plot No. | When 2 inches high. | Time of heading. | Milk stage. |
|---|---|---|---|
| 1. | 2 pounds of $NaNO_3$ dissolved in 25 gallons of water. | 25 gallons of water. | 25 gallons of water. |
| 2. | 2 pounds of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | Do. | Do. |
| 3. | ⅔ pound of $NaNO_3$ dissolved in 8½ gallons of water and 16½ gallons of water the day previous to the application of fertilizer. | ⅔ pound of $NaNO_3$ dissolved in 8½ gallons of water, and 16½ gallons of water the day previous to the application of the fertilizer. | ⅔ pound of $NaNO_3$ dissolved in 8½ gallons of water, and 16½ gallons of water the day previous to the application of the fertilizer. |
| 4. | ⅔ pound of $NaNO_3$ and 25 gallons of water the day previous to application of fertilizer. | ⅔ pound of $NaNO_3$ and 25 gallons of water the day previous to the application of the fertilizer. | ⅔ pound of $NaNO_3$ and 25 gallons of water the day previous to the application of the fertilizer. |
| 5. | 25 gallons of water. | 25 gallons of water. | 25 gallons of water. |

[5] Headden, W. P. Colo. Agr. Expt. Sta. Bul. 205.

[6] Occasion is hereby taken to express our gratitude to the late Dr. J. H. Kastle, director of the Kentucky Agricultural Experiment Station, for his courtesy in offering us the facilities of the station, and to Prof. E. J. Kinney, of the same station, for his assistance in carrying out the experiment.

| | | |
|---|---|---|
| 6. 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water previous to the application of fertilizer. | 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water the day previous to the application of the fertilizer. | 25 gallons of water. |
| 7. 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | Do. |
| 8. 25 gallons of water. | 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water the day previous to the application of fertilizer. | 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water the day previous to the application of fertilizer. |
| 9. Do. | 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. |
| 10. 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water the day previous. | 25 gallons of water. | 1 pound of $NaNO_3$ dissolved in 12½ gallons of water and 12½ gallons of water the day previous. |
| 11. 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | Do. | 1 pound of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. |
| 12. 25 gallons of water. | 2 pounds of $NaNO_3$ dissolved in 25 gallons of water. | 25 gallons of water. |
| 13. Do. | 2 pounds of $NaNO_3$ and 25 gallons of water the day previous to the application of fertilizer. | Do. |
| 14. Do. | 25 gallons of water. | 2 pounds of $NaNO_3$ dissolved in 25 gallons of water. |
| 15. Do. | Do. | 2 pounds of $NaNO_3$ and 25 gallons of water the day previous to |

| | | |
|---|---|---|
| | | the application of fertilizer. |
| 16. 2 pounds of $NaNO_3$. | No treatment. | No treatment. |
| 17. ⅔ pound of $NaNO_3$. | ⅔ pound of $NaNO_3$. | ⅔ pound of $NaNO_3$. |
| 18. 1 pound of $NaNO_3$. | 1 pound of $NaNO_3$. | No treatment. |
| 19. No treatment. | Do. | 1 pound of $NaNO_3$. |
| 20. 1 pound of $NaNO_3$ | No treatment. | Do. |
| 21. No treatment. | 2 pounds of $NaNO_3$. | No treatment. |
| 22. Do. | No treatment. | 2 pounds of $NaNO_3$. |
| 23. Do. | Do. | No treatment. |
| 24. 2 pounds of $NaNO_3$ and 2 pounds of KCl dissolved in 25 gallons of water. | 25 gallons of water. | 25 gallons of water. |
| 25. 25 gallons of water. | 2 pounds of $NaNO_3$ and 2 pounds of KCl dissolved in 25 gallons of water. | Do. |
| 26. Do. | 25 gallons of water. | 2 pounds of $NaNO_3$ and 2 pounds of KCl dissolved in 25 gallons of water. |
| 27. 2 pounds of KCl dissolved in 25 gallons of water. | Do. | 25 gallons of water. |
| 28. 25 gallons of water. | 2 pounds of KCl dissolved in 25 gallons of water. | Do. |
| 29. Do. | 25 gallons of water. | 2 pounds of KCl dissolved in 25 gallons of water. |
| 30. 2 pounds of $NaNO_3$ and 2 pounds of KCl. | No treatment. | No treatment. |
| 31. No treatment. | 2 pounds of $NaNO_3$ and 2 pounds of KCl. | Do. |
| 32. Do. | No treatment. | 2 pounds of $NaNO_3$ and 2 pounds of KCl. |
| 33. 2 pounds of KCl. | Do. | No treatment. |
| 34. No treatment. | 2 pounds of KCl. | Do. |
| 35. Do. | No treatment. | 2 pounds of KCl. |

### Results.

*Yield and Percentage of Grain in Crop.*—As seen from Table 1, only those plots which received the nitrate at the first stage of growth responded in yield to the application of this fertilizer. Of the 70 plots of the experiment 28 received varying amounts of sodium nitrate at the first stage, of which 10 received the nitrate at the rate of 320

pounds per acre, 12 at the rate of 160 pounds per acre, and 6 at the rate of 106⅔ pounds per acre. All these plots showed a decided response in yield, the response being distinctly proportional to the amount of nitrate applied at this stage of growth. The nitrate applied at the second and likewise at the third stage of growth did not seem to affect the vegetative growth of the crop in the slightest degree.

TABLE 1.—*Yield and percentage of grain from plots to which nitrate of soda was applied in various quantities at various stages of growth.*

| Fertilizer added at each application. | No. of applications. | Stages of growth. | Yield of grain, pounds. | | | Percentage of grain in crop. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water applied. | | No water applied. | Water applied. | | No water applied. |
| | | | Fertilizer in solution. | Fertilizer in solid state. | | Fertilizer in solution. | Fertilizer in solid state. | |
| 2 lbs. $NaNO_3$ | 1 | First | 34.0 | 34.2 | 29.6 | 34.9 | 33.3 | 31.2 |
| | | | 28.8 | 26.4 | 28.8 | 30.0 | 32.6 | 31.9 |
| Do. | 1 | Second | 14.7 | 17.0 | 15.8 | 35.9 | 36.4 | 38.1 |
| | | | 14.8 | 14.6 | 11.8 | 37.1 | 35.7 | 37.7 |
| Do. | 1 | Third | 16.3 | 14.8 | 16.3 | 36.8 | 36.0 | 40.0 |
| | | | 13.2 | 13.9 | 14.0 | 36.9 | 35.1 | 35.3 |
| 1 lb. $NaNO_3$ | 2 | First and second | 25.6 | 24.8 | 25.0 | 36.4 | 36.2 | 35.0 |
| | | | 27.2 | 24.4 | 26.4 | 36.0 | 35.7 | 36.7 |
| Do. | 2 | Second and third | 16.8 | 14.6 | 15.2 | 35.0 | 36.9 | 39.0 |
| | | | 12.2 | 14.2 | 12.6 | 39.5 | 39.5 | 35.3 |
| Do. | 2 | First and third | 25.6 | 23.8 | 25.0 | 33.3 | 34.9 | 37.5 |
| | | | 25.5 | 23.8 | 24.4 | 37.0 | 34.1 | 35.0 |
| 2/3 lb. $NaNO_3$ | 3 | First, second and third | 20.6 | 20.0 | 22.5 | 38.6 | 37.2 | 34.0 |
| | | | 21.2 | 21.0 | 25.3 | 37.1 | 34.1 | 35.5 |
| 2 lbs. $NaNO_3$ + 2 lbs. KCl | 1 | First | 32.2 | ...... | 32.1 | 37.8 | ...... | 39.6 |
| | | | 37.1 | ...... | 34.2 | 33.7 | ...... | 36.2 |
| Do. | 1 | Second | 14.4 | ...... | 15.2 | 37.8 | ...... | 40.5 |
| | | | 19.2 | ...... | 17.1 | 37.8 | ...... | 38.5 |
| Do. | 1 | Third | 14.8 | ...... | 13.0 | 37.3 | ...... | 40.5 |
| | | | 17.6 | ...... | 15.4 | 36.5 | ...... | 38.5 |
| 2 lbs. KCl | 1 | First | 14.4 | ...... | 16.6 | 39.0 | ...... | 33.5 |
| | | | 17.3 | ...... | 15.0 | 38.0 | ...... | 39.0 |
| Do. | 1 | Second | 14.6 | ...... | 15.0 | 28.2 | ...... | 32.6 |
| | | | 18.1 | ...... | 15.4 | 36.8 | ...... | 38.1 |
| Do. | 1 | Third | 14.5 | ...... | 12.4 | 37.5 | ...... | 32.4 |
| | | | 15.6 | ...... | 15.9 | 37.1 | ...... | 37.5 |
| Check | — | — | 18.8 | | 13.0 | 34.1 | | 35.3 |
| | | | 14.4 | | 16.3 | 36.8 | | 33.6 |

The plots to which nitrate was added in solid form showed the same tendency as those which received it in solution. It will be noticed, however, that of the plots which received their nitrate at the first stage, those which received it in solution showed a tendency to yield somewhat higher than those which received it in solid form. A possible explanation of this phenomenon lies in the fact that the

fertilizer was less evenly distributed in the plots to which it was applied in solid form. Certain spots in these plots probably received the nitrate at a rate which lies beyond the maximum point of its efficiency. This would naturally be at the expense of other spots in the same plots, which would have received the nitrate at a rate less than the nominal rate of application at this particular stage.

No appreciable differences have been noted with reference to the effect of the fertilizer on the ratio between grain and straw.

*Percentage of Yellowberry and the Protein Content.*—The terms "yellowberry" and "flinty" used in this paper refer only to the outer aspect of the grain, as the wheat used was a soft winter wheat with a starchy appearance inside. In determining the percentage of yellowberry in a sample any kernel which had the slightest trace of the characteristic yellow coloration was classed as yellowberry. This accounts for the degree of irregularity which is observed in the figures representing the percentage of yellowberry in a few of the samples. This irregularity, however, does not mask the general tendency, which is shown very distinctly. This tendency is still more accentuated when the grain of the individual samples is examined in mass.

As seen from Table 2, the samples grown on the plots which received an application of sodium nitrate in the second stage gave by far the highest protein content and the lowest percentage of yellowberry. This is clearly shown by every one of the 28 plots which received varying applications of the nitrate at the second stage. The protein content and the flintiness of the grain grown on those plots vary directly with the quantity of fertilizer received at this stage. It is therefore the presence of nitrate at the second stage which affected the coloration and the protein content of the grain. The grain grown on the plots to which the nitrate was applied at the first or third stage showed but a slight increase in protein.

It will be noticed that of the plots which received their nitrate in a single application those which received it at the third stage showed a tendency to give a somewhat higher protein content than those which received it at the first stage. It will be further noticed that of those plots which received their fertilizer in two applications those which received it at the second and third stages gave a distinctly higher protein content than those which received it at the first and second stages. It is possible that the third stage is more conducive to the formation of a somewhat higher nitrogen content in the grain than the first stage. It is also possible that the difference is due to the fact that the increased growth caused by the first application used up

more plant food and thus left less of the nitrate in the soil to affect the protein content of the grain.

TABLE 2.—*Percentage of yellowberry and protein content of wheat from plots to which nitrate of soda was applied in various quantities at three stages of growth.*

| Fertilizer added at each application. | No. of applications. | Stages of growth. | Percentage of yellowberry. | | | Percentage of protein. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water applied. | | | Water applied. | | |
| | | | Fertilizer in solution. | Fertilizer in solid state. | No water applied. | Fertilizer in solution. | Fertilizer in solid state. | No water applied. |
| 2 lbs. $NaNO_3$ | 1 | First | 35 | 28 | 23 | 10.85 | 10.80 | 10.88 |
| | | | 40 | 35 | 17 | 10.95 | 10.80 | 11.45 |
| Do. | 1 | Second | 0 | 0 | 1 | 13.63 | 13.18 | 13.87 |
| | | | 0 | 1 | 0 | 14.04 | 13.50 | 13.97 |
| Do. | 1 | Third | 41 | 35 | 60 | 10.92 | 10.68 | 10.94 |
| | | | 36 | 43 | 37 | 11.11 | 10.70 | 10.65 |
| 1 lb. $NaNO_3$ | 2 | First and second | 10 | 9 | 2 | 11.95 | 12.15 | 12.46 |
| | | | 10 | 6 | 10 | 11.87 | 12.13 | 12.03 |
| Do. | 2 | Second and third | 2 | 2 | 1 | 12.95 | 13.02 | 13.45 |
| | | | 1 | 4 | 3 | 13.50 | 13.60 | 13.10 |
| Do. | 2 | First and third | 34 | 33 | 37 | 10.65 | 10.48 | 10.57 |
| | | | 47 | 40 | 38 | 10.75 | 10.94 | 10.13 |
| 2/3 lb. $NaNO_3$ | 3 | First, second and third | 11 | 19 | 10 | 11.44 | 11.87 | 11.67 |
| | | | 18 | 30 | 15 | 11.44 | 11.80 | 11.53 |
| 2 lbs. $NaNO_3$ + 2 lbs. KCl | 1 | First | 34 | ...... | 33 | 10.73 | ...... | 11.17 |
| | | | 27 | ...... | 27 | 11.24 | ...... | 11.50 |
| Do. | 1 | Second | 1 | ...... | 1 | 13.99 | ...... | 13.79 |
| | | | 1 | ...... | 1 | 14.14 | ...... | 13.63 |
| Do. | 1 | Third | 40 | ...... | 40 | 11.07 | ...... | 11.38 |
| | | | 42 | ...... | 40 | 11.11 | ...... | 10.76 |
| 2 lbs. KCl | 1 | First | 71 | ...... | 65 | 10.03 | ...... | 10.38 |
| | | | 65 | ...... | 62 | 9.98 | ...... | 9.91 |
| Do. | 1 | Second | 68 | ...... | 71 | 9.82 | ...... | 10.18 |
| | | | 55 | ...... | 47 | 9.94 | ...... | 10.30 |
| Do. | 1 | Third | 70 | ...... | 72 | 10.00 | ...... | 9.39 |
| | | | 46 | ...... | 48 | 9.84 | ...... | 10.10 |
| Check | — | — | 64 | | 49 | 10.05 | | 10.01 |
| | | | 68 | | 40 | 9.76 | | 10.29 |

With reference to the coloration of the grain, there is some slight indication that those plots which received their nitrate in the first stage only gave a smaller percentage of yellowberry than those which received it at the third stage only. It is possible that it was due to the residual sodium nitrate left over in the soil from the first stage to be used by the plant at the second stage of growth.

When potassium chloride was used alone in any plot the percentage of yellowberry in the grain seemed to be increased.

*Weight per Bushel and Weight per 1,000 Kernels.* Table 3 shows that there is no consistent variation in the weight per 1,000 kernels and in the weight per bushel. The variations are slight and do not

seem to be affected by the various fertilizer treatments. In the work of Le Clerc and his associates there was a distinct correlation between the percentage of yellowberry, the protein content, and the weight per 1,000 kernels. The results of this experiment, while establishing a definite correlation between the percentage of nitrogen and the yellowberry, do not indicate any such correlation between the protein and the weight per 1,000 kernels. It is possible that this difference is due to the change in the variety of wheat. In the former experiments hard winter wheat was used, while in this experiment soft winter wheat was used. It is, however, also possible that the causes affecting the protein content and color of grain and those affecting weight per 1,000 kernels are not the same. Attention is drawn to the fact that the variation in the protein content in the former experiments of Le Clerc and his associates is much greater than in the one reported here.

TABLE 3.—*Weight per bushel and weight per 1,000 kernels of wheat from plots to which nitrate of soda was applied in various quantities and at various stages of growth.*

| Fertilizer added at each application. | No. of applications. | Stages of growth. | Weight per bushel. | | | Weight per 1,000 kernels. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water applied. | | No water applied. | Water applied. | | No water applied. |
| | | | Fertilizer in solution. | Fertilizer in solid state. | | Fertilizer in solution. | Fertilizer in solid state. | |
| 2 lbs. $NaNO_3$...... | 1 | First | 59.9 | 59.4 | 57.7 | 29.2 | 27.9 | 25.4 |
| | | | 58.3 | 58.8 | 57.2 | 27.2 | 27.0 | 27.8 |
| Do............... | 1 | Second | 59.1 | 59.7 | 60.2 | 25.1 | 25.9 | 28.0 |
| | | | 59.9 | 59.9 | 59.7 | 26.0 | 25.7 | 26.2 |
| Do............... | 1 | Third | 57.7 | 59.7 | 60.5 | 25.0 | 26.0 | 28.8 |
| | | | 59.4 | 59.4 | 58.3 | 25.1 | 24.1 | 27.2 |
| 1 lb. $NaNO_3$........ | 2 | First and second | 60.5 | 60.5 | 59.1 | 28.4 | 28.3 | 26.8 |
| | | | 59.4 | 59.9 | 59.4 | 30.5 | 27.1 | 26.6 |
| Do............... | 2 | Second and third | 59.9 | 59.7 | 59.4 | 27.2 | 27.0 | 26.4 |
| | | | 60.2 | 60.5 | 59.9 | 26.1 | 27.4 | 27.3 |
| Do............... | 2 | First and third | 59.4 | 58.6 | 59.4 | 28.0 | 26.8 | 29.0 |
| | | | 59.4 | 59.4 | 59.1 | 28.6 | 27.2 | 28.3 |
| 2/3 lb. $NaNO_3$...... | 3 | First, second and third | 60.5 | 60.5 | 59.4 | 30.3 | 28.3 | 27.0 |
| | | | 59.9 | 59.4 | 59.4 | 28.9 | 28.6 | 27.1 |
| 2 lbs. $NaNO_3$ + 2 lbs. KCl... | 1 | First | 60.2 | ...... | 59.9 | 28.0 | ...... | 29.9 |
| | | | 60.2 | ...... | 59.9 | 31.1 | ...... | 28.4 |
| Do............... | 1 | Second | 59.7 | ...... | 60.5 | 27.3 | ...... | 27.6 |
| | | | 60.2 | ...... | 60.2 | 27.5 | ...... | 26.7 |
| Do............... | 1 | Third | 59.4 | ...... | 59.7 | 27.0 | ...... | 29.4 |
| | | | 59.7 | ...... | 59.1 | 27.3 | ...... | 26.4 |
| 2 lbs. KCl.......... | 1 | First | 59.7 | ...... | 58.8 | 28.5 | ...... | 28.3 |
| | | | 59.7 | ...... | 59.9 | 27.8 | ...... | 28.1 |
| Do............... | 1 | Second | 60.5 | ...... | 59.1 | 28.6 | ...... | 28.3 |
| | | | 59.1 | ...... | 60.2 | 27.5 | ...... | 28.0 |
| Do............... | 1 | Third | 59.4 | ...... | 59.7 | 26.5 | ...... | 28.0 |
| | | | 59.1 | ...... | 59.1 | 26.3 | ...... | 26.9 |
| Check............ | — | — | 58.3 | | 59.4 | 27.3 | | 25.6 |
| | | | 59.4 | | 58.3 | 25.7 | | 23.7 |

SUMMARY.

1. The presence of sodium nitrate in the soil at the early stages of growth stimulated the vegetative growth of the crops and consequently gave greater yields.

2. The presence of sodium nitrate in the soil at the time of heading gave a better quality of grain with reference to color and protein content. The vegetative growth was, however, not in the least affected.

3. The presence of sodium nitrate in the soil at the milk stage of the grain had no effect on yield, quality, or protein content of the grain.

4. The same results were obtained from the plots which received their nitrate in solution and those which received it in solid form, except that the yields from the plots which received the fertilizer at the first stage were higher in the former case than in the latter. The reason for this is probably the better distribution of the fertilizer when applied in solution.

5. The use of potassium chloride did not affect the vegetative growth, nor did it appreciably affect the composition of the grain, but it did seem to increase the amount of yellowberry when used alone.

PLANT CHEMISTRY LABORATORY, BUREAU OF CHEMISTRY,
U. S. DEPARTMENT OF AGRICULTURE,
WASHINGTON, D. C.

# THE QUALITY OF WESTERN-GROWN SPRING WHEAT.[1]

C. H. BAILEY.

The crop year 1916 presented an unusual situation with regard to the marketing of the wheat grown in the Pacific Northwest. Ordinarily this wheat, grown principally in what is known as the Inland Empire, is marketed through Tacoma, Seattle, and Portland. Certain abnormal economic conditions, including high freight rates from the western ports and limited tonnage, have resulted in its transportation eastward by rail. Not since the rust-damaged spring wheat crop of 1904 has so large a quantity entered the markets of the Central States. Because of the short crop of rust-damaged wheat produced in the spring wheat area during the crop year of 1916, the attention of Central States millers is again being drawn to this western wheat, and an unusually large quantity is being utilized by them. Only a portion is being ground in these mills, however, much of it being consigned for export through eastern ports.

In addition to the varieties commonly grown in the Pacific Northwest, a considerable acreage of Marquis wheat was sown this past season. A part of this was shipped to the Minnesota markets during September, 1916. Some of the first consignments were so soft and starchy as to render difficult a classification based on the physical characteristics of the kernels. The yellowberry condition had resulted in the loss of the usual angularity of the edges of the cheek and crease of the kernel, which had a rotundity common to certain other varieties.

Tests were made of some of these first shipments of Marquis wheat, and the results showed them to be inferior to the average of the same variety of wheat grown in the Great Plains area. The writer therefore proceeded to those sections of Montana, Idaho, and Washington which were shipping grain of this variety, and collected a number of samples in order to ascertain the comparative quality of each. To afford a comparison with the varieties of wheat more commonly produced in the same areas, a number of samples of other kinds of wheat were collected at the same time. These were tested in the

[1] Contribution from the Minnesota Grain Inspection Department Laboratory. Received for publication January 27, 1917.

manner usual to this laboratory, namely, by grinding them in the experimental roller mill, thus producing a white middlings flour which was baked into bread under controlled conditions.[2] The percentage of crude protein in the wheat was also determined.

It was found that the greater part of the Marquis wheat produced in the Inland Empire is raised in the Palouse district near Pullman, Wash., and Moscow, Idaho, and in the Nez Perce district, particularly around Genesee and Lewiston, Idaho, and on the Camas Prairie between Reubens and Grangeville, Idaho. This variety is particularly adapted to the higher altitudes of the Camas Prairie, since it matures sufficiently early to avoid the frost of late summer. The Vollmer-Clearwater Company of Lewiston, Idaho, has been largely instrumental in introducing and encouraging the production of Marquis wheat in this portion of the Nez Perce district.

Marquis wheat was first grown in these localities in any considerable quantity during the season of 1914; the increase was sold for seed, and it was not until the fall of 1916 that it was shipped to any extent. The larger part of the Marquis wheat acreage was sown in the spring, although occasional fields were fall-sown. In and around Culdesac, Idaho, it was reported that the larger part was being sown in the fall; this is the only locality visited where the reverse was not true. The experiment station at Moscow, Idaho, reported materially larger yields from the spring-sown plots of this variety than from those sown in the fall.

It was observed that in general those samples of Marquis wheat grown at the lower altitudes were decidedly high in their content of yellowberry kernels, while those grown at higher altitudes were generally corneous and dark red in color. The chemical analyses and baking tests of these samples paralleled their appearance quite closely, the corneous samples being higher in crude protein and in baking strength than those consisting largely of yellowberries. The relation between altitude and hardness of the grain was not exact in all cases, however, certain other environmental influences occasionally counteracting the general relation observed. The samples collected at Lewiston, Culdesac, and Ferdinand, in Idaho, serve to illustrate the differences between lots grown at different altitudes. Lewiston is at an altitude of 742 feet, although the adjacent farming land is somewhat higher than this; Culdesac is 1,620 feet above sea level, and Ferdinand, 3,728 feet. The average percentages of crude protein in the Marquis

[2] The milling methods are described in Minn. Agr. Expt. Sta. Bul. 131 and 143; the baking method in Jour. Indus. Engin. Chem., 8: 53–57, Jan., 1916.

wheat samples collected at these three stations were as follows: Lewiston, 8.93; Culdesac, 9.83; and Ferdinand, 11.38. The last average does not include the sample taken from a lot which had been allowed to become dead ripe before harvest (Lab. No. 207a), and which contained only 7.87 percent of crude protein. The relation between altitude and protein content is doubtless due to the materially shorter season at the higher altitudes. It is generally true that, other things being equal, a short growing season results in higher percentages of protein and harder kernels than when the seasons are long.

The Marquis wheat grown on the experiment station farm at Pullman, Wash., was materially higher in protein content and in baking strength than any of the other varieties produced there of which samples were obtained. The Turkey (winter) and Early Baart (spring) were about equal, the latter being slightly lower in percentage of protein, but giving a larger loaf. The yield of flour was greater from the Turkey, however. The common soft white and red wheats grown at Pullman were inferior in these respects to the three varieties mentioned, the Jones Winter Fife being the poorest, followed closely by Red Russian and Fortyfold. Two samples of Marquis wheat grown near Pullman and obtained through Mr. W. M. Chambers were decidedly inferior to the sample from the experiment station. They contained 8.09 and 8.49 percent, respectively, of crude protein and were correspondingly low in baking strength.

The Marquis wheat obtained at the Idaho experiment station, Moscow, contained almost the same percentage of crude protein as the Pacific (Palouse) Bluestem from the same farm, but gave a larger and better loaf of bread. No Early Baart wheat was obtained at Moscow.

Lind, Wash., in what is known as the Big Bend district, was visited, and a number of samples of spring wheats typical of this district were obtained. The Big Bend district is characterized by its low rainfall, and the samples of Early Baart and Pacific Bluestem grown in the vicinity of Lind reflect that condition in their relatively high protein content and baking strength. The average percentage of crude protein in the Early Baart samples was 13.10, and in the Pacific Bluestem, 12.74. The average loaf volume was practically the same in the case of both varieties, being 1,473 and 1,470 c.c., respectively, while the average of the expansimeter tests was the same, viz., 687 c.c. There was a decided difference in protein content and baking strength between the samples of these two varieties grown in the Big Bend

district and those grown at Pullman, Wash., in the Palouse district, the latter being lower in both respects.

The larger part of the wheat grown in the Big Bend is spring sown. Early Baart ordinarily matures several days earlier than the Pacific Bluestem; this past season the fomer was affected by a drought just before it matured, which reduced the yield, while a late rain stimulated the Bluestem to a greater development, and the yields of it were larger than those of the Early Baart. Under normal conditions the property of maturing early would be an advantage, since a rain in the late summer is unusual in this district, and the Early Baart should accordingly be preferred to Bluestem. The farmers are dissatisfied with their experience with the Early Baart, however, and the probabilities are that less of it and more of the Bluestem will be seeded in the spring of 1917.

In the principal wheat-growing sections of Montana a thaw followed by a freeze early in the spring of 1916 killed most of the fall-sown Turkey wheat. A large part of this acreage was accordingly reseeded in the spring to Marquis wheat, and the total production of the latter was much in excess of the normal. A number of samples of Marquis and Turkey wheat were obtained in different parts of the Gallatin Valley and in the Judith Basin. The dry-farmed Marquis wheat of the 1916 crop grown in the Gallatin Valley was apparently quite uniformly high in protein and also in baking strength. The sample of irrigated Marquis grown at Amsterdam, in this valley, was much poorer in quality than the dry-farmed wheat from a neighboring farm. A sample of 1915-crop Marquis, said to be typical of that crop from near Belgrade, Mont., proved to be inferior to the 1916 crop from the same station. Many of the 1916-crop samples of this variety were badly mixed with Turkey winter wheat, which survived the freeze and matured its grain. The Turkey wheat grown in the Gallatin Valley, while fairly high in protein content, did not yield as satisfactory loaves of bread as the spring wheat from the same localities.

Marquis wheat raised tributary to Lewistown, Mont., in the Judith Basin, also possessed very satisfactory milling and baking qualities. There was less difference between the Marquis and the Turkey samples obtained in the Judith Basin in these regards than there was in the Gallatin Valley samples. Such differences as were found were, on the average, in favor of the spring Marquis, although there was an overlapping in the cases of the individual samples.

Data from the milling and baking tests and on the crude protein content are given in Table 1.

TABLE 1.—*Data obtained from milling and baking tests of Washington, Idaho, and Montana wheats, with the percentage of crude protein in each.*

WESTERN HARD SPRING WHEATS.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Percent.* | *c.c.* | *c.c.* | *Percent.* | | | *Percent.* |
| 167*a* | No. 1 Western red ... | N.P. 33322 .... | 75.8 | 560 | 1,340 | 61.3 | 98 | 94 | 8.21 |
| 168*a* | Marquis..... | N.P. 32952 .... | 75.2 | 540 | 1,290 | 62.6 | 99 | 90 | 7.89 |
| 169*a* | Marquis No.1 | N.P. 44410 .... | 75.6 | 650 | 1,300 | 62.6 | 98 | 96 | 9.03 |
| 170*a* | No. 1 ....... | C.P. 120128 ... | 75.6 | 690 | 1,360 | 63.7 | 100 | 97 | 9.46 |
| 171*a* | ..do........ | N.P. 29785 .... | 73.6 | 730 | 1,440 | 63.7 | 101 | 99 | 11.51 |
| 180*a* | Marquis..... | Pullman, Wash. | 73.6 | 750 | 1,510 | 64.6 | 102 | 100 | 11.46 |
| 187*a* | ..do........ | ......do....... | 74.9 | 690 | 1,330 | 65.3 | 98 | 98 | 8.09 |
| 189*a* | ..do........ | ......do....... | 74.0 | 660 | 1,360 | 67.5 | 100 | 99 | 8.49 |
| 188*a* | ..do........ | Genesee, Idaho | 72.2 | 680 | 1,310 | 66.8 | 99 | 98 | 8.21 |
| 193*a* | ..do........ | Moscow, Idaho | 75.4 | 650 | 1,390 | 67.1 | 100 | 98 | 10.06 |
| 194*a* | ..do........ | Lewiston, Idaho | 74.0 | 610 | 1,310 | 63.5 | 101 | 100 | 8.70 |
| 197*a* | ..do........ | ......do....... | 74.9 | 660 | 1,360 | 62.6 | 102 | 99 | 8.92 |
| 198*a* | ..do........ | ......do....... | 75.2 | 630 | 1,320 | 63.3 | 102 | 94 | 9.18 |
| 200*a* | ..do........ | Fort Lapwai, Idaho........ | 75.1 | 670 | 1,450 | 62.2 | 101 | 99 | 10.54 |
| 201*a* | ..do........ | Culdesac, Idaho | 73.2 | 730 | 1,460 | 65.5 | 103 | 100 | 10.49 |
| 202*a* | Marquis (fall) | ......do....... | 72.6 | 650 | 1,360 | 62.2 | 100 | 93 | 9.41 |
| 203*a* | Marquis..... | ......do....... | 72.8 | 570 | 1,290 | 62.8 | 101 | 93 | 9.59 |
| 204*a* | ..do........ | Ferdinand, Ida. | 72.4 | 690 | 1,380 | 66.2 | 101 | 98 | 10.55 |
| 205*a* | ..do........ | ......do....... | 72.4 | 700 | 1,430 | 65.5 | 102 | 100 | 11.69 |
| 206*a* | Marquis (cut green)..... | ......do....... | 69.8 | 660 | 1,430 | 65.3 | 100 | 99 | 11.91 |
| 207*a* | Marquis (cut ripe)...... | ......do....... | 70.5 | 500 | 1,280 | 64.0 | 101 | 99 | 7.87 |
| 218*a* | No. 2 ....... | Lewistown, Mont....... | 70.0 | 700 | 1,470 | 64.8 | 102 | 99 | 11.46 |
| 219*a* | No. 1 ....... | ......do...... | 72.8 | 740 | 1,510 | 64.8 | 98 | 95 | 12.34 |
| 223*a* | Marquis....: | ......do...... | .70.9 | 750 | 1,560 | 65.5 | 100 | 100 | 10.11 |
| 225*a* | Marquis (dry-farmed) ... | Amsterdam, Mont....... | 70.5 | 760 | 1,550 | 65.5 | 98 | 99 | 13.22 |
| 226*a* | Marquis..... (irrigated). | ......do...... | 72.5 | 600 | 1,300 | 63.5 | 99 | 98 | 9.63 |
| 227*a* | Marquis..... | Manhattan, Mont....... | 72.3 | 740 | 1,510 | 63.3 | 100 | 98 | 12.14 |
| 228*a* | Marquis (1915).... | Belgrade, Mont. | 75.1 | 630 | 1,350 | 63.1 | 101 | 100 | 8.83 |
| 229*a* | Marquis (1916).... | ......do....... | 72.7 | 680 | 1,480 | 67.7 | 97 | 97 | 11.23 |
| | Average..... | | 73.3 | 666 | 1,394 | 64.3 | 100 | 97½ | 10.01 |

WESTERN HARD WINTER WHEATS.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| 173*a* | Turkey...... | Pullman, Wash. | 74.1 | 560 | 1,300 | 66.2 | 98 | 94 | 10.07 |
| 196*a* | Turkey (mixed) ... | Lewiston, Idaho | 72.3 | 560 | 1,400 | 68.4 | 99 | 98 | 8.21 |
| 199*a* | Turkey...... | ......do....... | 73.1 | 670 | 1,420 | 66.0 | 102 | 99 | 11.57 |
| 217*a* | ..do......... | R.I. 31803 (Spokane)... | 72.6 | 620 | 1,450 | 65.1 | 99 | 98 | 10.29 |

WESTERN HARD WINTER WHEATS.—*Continued.*

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Percent.* | *c.c.* | *c.c.* | *Percent.* | | | *Percent.* |
| 220*a* | No. 2 Mont. Winter.... | Lewistown, Mont........ | 70.8 | 700 | 1,510 | 69.9 | 100 | 97 | 12.34 |
| 221*a* | No. 3 Mont. Winter.... | ......do...... | 69.0 | 630 | 1,490 | 66.2 | 99 | 94 | 12.65 |
| 222*a* | Turkey...... | ......do...... | 73.6 | 610 | 1,450 | 67.3 | 100 | 95 | 9.29 |
| 224*a* | ..do........ | Manhattan, Mont........ | 72.7 | 610 | 1,310 | 66.2 | 98 | 95 | 11.26 |
| 230*a* | ..do........ | ......do...... | 70.5 | 600 | 1,350 | 67.7 | 98 | 99 | 11.63 |
| | Average..... | .............. | 72.1 | 618 | 1,410 | 67.1 | 99 | 96½ | 10.81 |

WESTERN SOFT RED WHEATS.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| 172*a* | Wash. Hybrid No. 123... | Pullman, Wash. | 71.6 | 560 | 1,250 | 67.3 | 97 | 95 | 9.30 |
| 174*a* | Jones Winter Fife...... | ......do....... | 71.7 | 430 | 1,120 | 62.2 | 99 | 92 | 9.26 |
| 175*a* | Red Russian | ......do....... | 72.2 | 430 | 1,160 | 62.2 | 96 | 92 | 8.93 |
| 190*a* | ....do...... | Moscow, Idaho | 72.8 | 530 | 1,220 | 62.6 | 95 | 85 | 10.29 |
| 215*a* | Jones Winter Fife...... | Lind, Wash.... | 71.9 | 480 | 1,120 | 61.3 | 98 | 75 | 9.12 |
| 163*a* | Crail Fife.... | Montana...... | 71.2 | 510 | 1,110 | 56.8 | 99 | 90 | 9.86 |
| | Average..... | .............. | 71.9 | 490 | 1,163 | 62.1 | 97 | 88 | 9.46 |

EARLY BAART WHEAT.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| 181*a* | Early Baart . | Pullman, Wash. | 71.3 | 660 | 1,350 | 62.0 | 100 | 99 | 9.82 |
| 209*a* | ....do...... | Lind, Wash.... | 70.2 | 730 | 1,510 | 62.6 | 102 | 98 | 13.91 |
| 210*a* | ....do...... | ....do........ | 71.6 | 670 | 1,490 | 62.2 | 100 | 96 | 12.48 |
| 211*a* | ....do...... | ....do........ | 70.9 | 660 | 1,420 | 62.0 | 101 | 99 | 12.92 |
| 216*a* | ....do...... | R. I. 35117 (Spokane)... | 69.6 | 620 | 1,440 | 59.3 | 99 | 98 | 11.38 |
| | Average..... | .............. | 70.7 | 668 | 1,442 | 61.6 | 100 | 98 | 12.10 |

PACIFIC BLUESTEM WHEAT.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| 212*a* | Pacific Bluestem...... | Lind, Wash.... | 70.4 | 730 | 1,500 | 61.3 | 100 | 99 | 12.94 |
| 213*a* | .....do..... | ....do........ | 69.0 | 620 | 1,430 | 61.1 | 100 | 99 | 12.31 |
| 214*a* | .....do..... | ....do........ | 69.6 | 710 | 1,480 | 62.4 | 101 | 98 | 12.97 |
| 185*a* | .....do..... | Pullman, Wash. | 72.7 | 510 | 1,280 | 60.8 | 96 | 94 | 9.21 |
| 192*a* | .....do..... | Moscow, Idaho | 73.9 | 480 | 1,280 | 63.3 | 95 | 90 | 10.03 |
| 195*a* | .....do..... | Lewiston, Idaho | 73.3 | 520 | 1,350 | 61.5 | 97 | 94 | 8.35 |
| 208*a* | .....do..... | Ferdinand, Idaho....... | 72.2 | 520 | 1,300 | 60.2 | 94 | 92 | 8.26 |
| | Average..... | .............. | 71.6 | 584 | 1,374 | 61.5 | 97½ | 95 | 10.58 |

OTHER WESTERN WHITE WHEATS.

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| 176*a* | Little Club (fall)...... | Pullman, Wash. | 72.7 | 570 | 1,290 | 63.5 | 94 | 95 | 10.74 |
| 186*a* | Little Club (spring)... | ......do....... | 73.2 | 550 | 1,320 | 61.1 | 96 | 96 | 9.27 |
| 177*a* | Wash. Hybrid No. 128... | ......do....... | 73.5 | 490 | 1,210 | 60.8 | 95 | 90 | 10.20 |

OTHER WESTERN WHITE WHEATS.—*Continued.*

| Lab. No. | Variety. | Source. | Total flour. | Expansimeter test. | Loaf volume. | Water used. | Color score. | Texture. | Crude protein in wheat. |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Percent.* | *c.c.* | *c.c.* | *Percent.* | | | *Percent.* |
| 179*a* | Wash. Hybrid No. 143 (fall) | Pullman, Wash. | 71.9 | 480 | 1,220 | 63.3 | 96 | 95 | 9.89 |
| 184*a* | Wash. Hybrid No. 143 (spring) | ......do...... | 71.9 | 520 | 1,280 | 59.1 | 97 | 97 | 8.61 |
| 178*a* | Fortyfold.... | ......do...... | 72.4 | 410 | 1,180 | 60.4 | 97 | 92 | 10.57 |
| 18[illegible]*a* | Dicklow..... | ......do...... | 71.6 | 570 | 1,290 | 61.7 | 98 | 95 | 8.16 |
| 183*a* | Red Allen... | ......do...... | 71.8 | 620 | 1,310 | 60.0 | 100 | 96 | 9.38 |
| 191*a* | Fortyfold.... | Moscow, Idaho | 74.1 | 460 | 1,170 | 61.7 | 97 | 70 | 9.72 |
| | Average..... | .............. | 72.6 | 519 | 1,252 | 61.3 | 96½ | 92 | 9.62 |

## Summary.


The quantity of Marquis wheat produced in the Pacific Northwest and Montana during the crop year of 1916 was much larger than usual. This was due to an increased acreage of this variety in certain sections of the Inland Empire, and to the reseeding of the winter wheat fields which had been frozen out early in the season in sections of Montana.

Marquis wheat grown at Pullman, Wash., was higher in protein content and baking strength than any of the common varieties of which samples were obtained. The lots of this variety which were grown at the lower altitudes were in general materially lower in baking value and percentage of crude protein than those grown at the higher altitudes. The difference is attributed to the shorter growing season under the latter conditions.

Early Baart wheat samples which were grown in the Big Bend district of Washington near Lind were higher in the percentage of crude protein and nearly as satisfactory from the baking standpoint as the average of the spring wheat produced east of the divide and in the northern Great Plains district.

Marquis wheat produced under dry-farm conditions in Montana was of good milling and baking quality and was somewhat superior in these respects to the Turkey winter wheat grown in the same districts.

The soft red and white wheats of the Inland Empire district, such as Jones Winter Fife, Little Club, Red Russian, and Fortyfold, are generally inferior in baking qualities to Marquis and Turkey wheat grown in the same sections.



MINNESOTA GRAIN INSPECTION DEPARTMENT LABORATORY,
MINNEAPOLIS, MINN.

# GREEN MANURING: A REVIEW OF THE AMERICAN EXPERIMENT STATION LITERATURE—3.

A. J. PIETERS.

## WESTERN SECTION.

The western section includes the Great Plains, Intermountain, and Pacific Coast States and the Western Provinces of Canada. In this section the green-manure or rotation work has been conducted with a variety of plants rather than with any one species particularly. In the western United States alfalfa is the greatest leguminous forage plant and in these States also the moisture supply rather than the humus content is often the critical factor.

### CALIFORNIA.

Wheat yields were increased on sandy soil in the San Joaquin Valley by turning under green manures as reported in Bulletin 211 (1911). One plot was fallowed while on others horse beans, Canada field peas, rye and vetch, and rye alone were turned under in the spring of 1908 and the plots fallowed till the next fall, when wheat was sown. The average yield of wheat during 1909 and 1910 was as follows:

| | |
|---|---|
| After fallow | 33.3 bushels. |
| After horse beans | 37.6 bushels. |
| After Canada field peas | 36.5 bushels. |
| After rye and vetch | 54.0 bushels. |
| After rye | 52.3 bushels. |
| After wheat (in 1909 only) | 15.7 bushels. |

The stand of horse beans and peas is said to have been fairly good and that of rye excellent. In this experiment the summer fallow after plowing under the green crops gave opportunity for complete decay and the rye gave better results than the legumes.

On the heavier soil at Davis, Cal. (Bul. 211, p. 268), wheat after wheat (average of two plots) yielded 35.6 bushels; wheat after green manures turned under, 44.3 bushels; and wheat after fallow (one plot), 41.6 bushels. Here also there was a small but evident benefit from green manure.

A comparison of green manuring with fallowing and with continuous cropping on the yield of wheat is made in Bulletin No. 270. All plots were fallowed in 1906–7, after which some received green manure, others were fallowed, and on two plots wheat was grown continuously for six years. The results show that the total yields for six years on the continuous grain plots was a little better than on the best treated plots for three years but also that on the continuous grain plots there was a steady and great decrease in yields while on the treated plots this decrease, if any, was small. A consideration of the yields during the last four years of the experiment shows that generally the green-manure plots have yielded a little less than the fallow plot, which has yielded more in one year than the continuous plot has in two. The author concludes that at present it is profitable to fallow but not to grow and turn under green-manure crops.

In an experiment conducted at the Citrus Station, Riverside, Cal. (Report, 1913–14, p. 62), the relative value of a legume or a nonlegume proved to be very different from that in the San Joaquin experiment referred to above. The experiment at Riverside was commenced in 1909 and each year winter green-manure crops were grown, plowed under in spring, and corn, potatoes, and sugar beets raised in the summer. Barley was the nonlegume used and to some of the plots on which barley was turned under nitrate of soda varying in quantity from 270 to 1,080 pounds per acre was applied after the summer crop began growth. The report of 1913–14 gives the 4-year average yield of corn, 2-year average yield of potatoes, and 2-year average yield of beets, as shown in Table 10.

TABLE 10.—*Yields of corn, potatoes, and beets at Riverside, Cal., after leguminous and nonleguminous green-manure crops.*

| Previous treatment. | Yield per acre. | | |
|---|---|---|---|
| | Corn. | Potatoes. | Beets. |
| | *Bushels.* | *Bushels.* | *Tons.* |
| Average on all legume plots | 40.00 | 226 | 17.9 |
| Average on barley plots without nitrate of soda (4 plots) | 29.75 | 161 | 12.3 |
| Barley plot with 270 lbs. nitrate of soda | 32.00 | 166 | 12.5 |
| Barley plot with 540 lbs. nitrate of soda | 42.00 | 204 | 15.7 |
| Barley plot with 810 lbs. nitrate of soda | 34.00 | 191 | 16.0 |
| Barley plot with 1,080 lbs. nitrate of soda | 41.00 | 218 | 17.7 |

On some of the legume plots, as on that on which *Melilotus indica* was turned under, the yields considerably exceeded any on the barley plus nitrate plots, the yield of corn being 46 bushels, potatoes 252 bushels, and beets 19.8 tons.

CANADA.

At both the Brandon and Indian Head experimental farms a series of rotations were commenced in 1898 in which a legume was turned under every third year. At the Brandon Farm the old series was abandoned in 1905 and a new one commenced, but at the Indian Head Farm the records are complete for ten years. While certain minor changes in the rotations were made toward the end of the series the main plan has been carefully carried out. The record from the Indian Head Farm is the more satisfactory, but in general the results at the two farms are in harmony.[5]

At the Indian Head Farm 22 plots were laid out in 1899. Nos. 1 to 5, inclusive, had grain in 1899 and 1900 and a legume turned under in 1901; Nos. 6 to 10, inclusive, had a legume in 1899 and grain in 1900 and 1901; No. 11, rape in 1899, wheat in 1900, and fallow in 1901; Nos. 12, 13, and 14, grain two years with fallow in 1901; Nos. 15 and 16, continuous grain; Nos. 17 to 21, inclusive, grain in 1899, legume in 1900, and grain in 1901; while No. 22 was fallow in 1900 and had grain in 1899 and 1901. There were thus three series of plots in which a legume to be turned under appeared every third year. The work on these plots ended with the crop of 1909.

In Table 11 the yields of wheat for the last year in which this crop appeared have been given for the legume rotation plots, together with the yields on fallow and continuous rotation plots so far as possible. Since oats, barley, and rye were also raised, on some plots these crops occurred in the years in question and so all plots are not included in the table. The results shown indicate that even after three or four crops of legumes had been turned under in the course of ten years the average yield was not increased over that from fallowed land, though the increase over continuous grain growing was marked.

In the report for the year ending March, 1910 (p. 352), the average yields of grain for the 5-year period from 1905 to 1909 on the Brandon Farm are given. On these plots legumes had been turned under one or two years with grain (mostly wheat) for three or four years. The fallow plots had been in grain four years and fallow one. The average yield of wheat only on plots that had had two legume crops turned under was 33.4 bushels. The average yield on three plots fallow one year and in grain four years was 35.12 bushels, while the continuous grain plots produced an average of 29.13 bushels of wheat. It is clear that at Brandon and Indian Head for the time

[5] Reports on this series are found in the following Experimental Farms Reports—1899, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1908, 1909, 1910, and 1912.

during which this series of experiments was conducted, green manuring has shown no benefit over fallowing. An isolated test of sweet clover *vs.* fallow at the Brandon Farm (Report 1898, p. 274) showed that wheat yielded better after fallow than after sweet clover, but better after sweet clover than after wheat stubble.

TABLE II.—*Yields of wheat on the Indian Head, Sask., Farm in 1907, 1908, or 1909, in 3-year rotations including one legume, in similar rotations including fallow, and on continuous grain plots.*

| Plot No. | Legume crops since 1898. | Yields of wheat, bushels per acre. | | |
|---|---|---|---|---|
| | | 1907. | 1908. | 1909. |
| 17 | 2 crops of soybeans, 1 of alsike | 18.17 | | |
| 18 | 3 crops of peas | 15.93 | | |
| 19 | 3 crops of tares | 12.93 | | |
| 20 | 3 crops of red clover | 23.30 | | |
| 21 | 3 crops of alfalfa and alsike | 12.40 | | |
| | Average for legume plots | 16.55 | | |
| 22 | No legumes, fallow three times | 23.10 | | |
| 1 | 2 crops soybeans, 1 of peas | ......... | 31.27 | |
| 2 | 2 crops peas, 1 of tares | ......... | 32.00 | |
| 3 | 2 crops tares, 1 of alsike | ......... | 30.60 | |
| 4 | 3 crops of red clover | ......... | 29.83 | |
| 5 | 3 crops of alfalfa and alsike | ......... | 31.67 | |
| | Average of legume plots | ......... | 31.07 | |
| | Average of 3 fallow plots | ......... | 33.12 | |
| | Average of 2 continuous grain plots | ......... | 14.18 | |
| 6 | 4 crops of peas | ......... | ......... | 12.27 |
| 7 | 4 crops of tares | ......... | ......... | 14.40 |
| 8 | 3 crops of soybeans, 1 of alsike | ......... | ......... | 13.53 |
| 9 | 4 crops of red clover | ......... | ......... | 15.73 |
| 10 | 4 crops of alfalfa and alsike | ......... | ......... | 16.73 |
| | Average of legume plots | ......... | ......... | 14.53 |
| 11 | No legumes—2 crops rape, timothy in 1905, fallow in 1901, 1904, and 1907, wheat in 1908 | ......... | ......... | 15.37 |
| 12 | Fallow in 1901, 1904, 1907, wheat in 1908 | ......... | ......... | 14.53 |
| 15 | Continuous grain | ......... | ......... | 8.47 |

## COLORADO.

Potatoes on alfalfa sod yielded from two to five times as much as on land that had been manured two years before and had raised one crop of grain and one of corn (Bul. 57). A gain in the yield of potatoes on alfalfa land is also reported in Bulletin No. 117.

## KANSAS.

In 1891 an extensive series of rotation experiments was planned (Bul. 20). Reports of yields from these plots were made in 1892 (Bul. 33) and in 1894 (Bul. 47), but no conclusions can be drawn from them. The last reference found to this series is in Bulletin 128 (1904), but nothing of importance is added to the previous informa-

tion. It is to be regretted that a series so carefully planned was not carried out to its conclusion, as valuable data might have been obtained.

In Bulletin 144 (1907) records are given from a 2-year rotation experiment in which wheat followed various crops. The average yield of wheat after wheat on all plots during 1905 and 1906 was 31.9 bushels; wheat after soybeans, 28.8 bushels; and wheat after millet, 33.0 bushels. Soybeans was the only leguminous crop used. All crops were harvested. The average yields of corn for the three years from 1904 to 1906 on a few representative plots selected from the entire record (Bul. 147) were as follows:

| | |
|---|---|
| After oats | 51.49 bushels. |
| After flax | 53.12 bushels. |
| After millet | 57.21 bushels. |
| After corn | 53.70 bushels. |
| After corn and cowpea catch crop | 54.30 bushels. |
| After corn and rye catch crop | 54.20 bushels. |
| After soybeans | 67.50 bushels. |
| After potatoes | 69.96 bushels. |

While these rotations have not run long enough to warrant the conclusion that cowpeas as a catch crop have no special value, the authors do conclude that "the second largest average yield of corn, 67.50 bushels per acre, was produced after soybeans, and offers a good illustration of the value of legume crops for increasing the available nitrogen in the soil, preparatory to growing large crops of corn or other heavy nitrogen feeding crops." They appear to overlook the fact that the yield after potatoes was larger than that after soybeans and that when a legume (cowpea) was used as a catch crop the yield of corn was not materially increased in the time of the experiment. It may be noted here that in Bulletin 100 (1901) the statement is made that "the yields of crops of all kinds is increased where they follow soybeans, wheat showing in large fields an increase of 5 bushels per acre when following soybeans over that grown on adjoining land that had not been in beans. This increase is shown where soybeans bearing no tubercles have been grown." No experimental data for this statement are offered.

In Bulletin 160 (1909) 5-year averages of corn and wheat following one year of cowpeas or soybeans are given. Wheat averaged less after the legume, which is said to have been due to lodging as a result of rank growth. Corn yields were higher after legumes, 66.53 bushels, as compared with 52.30 bushels for continuous culture.

In 1906 it was found (Bul. 175, 1911) that wheat following cowpeas on newly broken sod gave larger yields than when following corn or small grain. The yields after fallow on this newly broken sod were about the same as after cowpeas.

W. E. Watkins in the annual report of the Allen County Farm Bureau for 1915 has presented the records for a number of 1-year experiments on the value of sweet clover and cowpeas to precede corn and wheat. The various records have been condensed in Table 12.

TABLE 12.—*Yields of wheat and corn after one year of sweet clover or cowpeas, as compared with yields from nonlegume plots.*

| Crop. | Yield in bushels per acre. | | | |
|---|---|---|---|---|
| | After sweet clover. | Check. | After cowpeas. | Check. |
| Wheat | 16.0 | 9.0 | — | — |
| Corn | 54.0 | 32.4 | 62.5 | 21.0 |
| Do. | 35.0 | 25.0 | 46.6 | 26.8 |
| Do. | — | — | 40.0 | 30.0 |

NEBRASKA.

A rotation and green-manure experiment was carried on from 1907 to 1914 in which oats and other grains followed various crops (Bul. 155). The green-manure crops, field peas and rye, were plowed under when in bloom and were followed by oats only. The average yields over the eight years show that while on spring-plowed land oats after oats yielded 16.3 bushels per acre, after rye plowed under they yielded 21.7 bushels per acre and after peas plowed under, 22.2 bushels. After corn and after spring wheat the yields were 19.6 and 19.4 bushels respectively, while on summer-tilled land 27.4 bushels were produced. While the use of green-manure crops returned a larger yield than continuous grain culture the yields were smaller than on fallow land, and the legume green-manure crop was practically no better than rye. The authors add that the additional expense of the green-manure crop made its use unprofitable. In the Annual Report of the Nebraska Corn Improvers' Association, 1912, pages 73–75, a member records an observation showing that under certain conditions the plowing under of alfalfa may have a bad effect on the succeeding crop. Corn failed to produce ears while on adjoining land on which a legume never had been grown a crop of 40 bushels per acre was harvested.

NORTH DAKOTA.

In 1892 an extensive rotation experiment was planned and outlined in Bulletin 10. The land had been uniformly cropped from 1883 to 1891. The author, W. M. Hays, says that "this piece of land is as nearly uniform, so far as the eye can judge, as any 40 acres of land I ever saw." Partial reports on this work may be found in Bulletins 11, 23, 39, and 48, and a complete record of yields is published in Bulletin 100, on which the following discussion is based. It was inevitable that all plots should not be in wheat each year and so comparisons can be made only for certain years and between certain plots.

Plot 19 was continuously in wheat for eight years, from 1892 to 1899, inclusive, but 2 to 3 pounds of red clover seed was sown with the grain, the clover being turned under for the next crop of wheat. Plots 14, 24, and 25 were the nearest continuous wheat plots without clover. The average annual yield was nearly 2 bushels higher on plot 19 than that from plots 14, 24, and 25. In a letter Professor Shepperd has also pointed out that in the eight years "there have been on plots 14, 24, and 25, three crops larger and twenty smaller than those on plot 19." The yield on plot 19 was also from 2 to 4 bushels more than that obtained from plots 21, 22, and 23, on which other small grain alternated with wheat.

On plots 7 and 8 field peas were grown one year in four; the peas were cut on plot 7 and turned under on plot 8. On page 35 the authors analyzed the results from these plots, comparing the yields with those on continuous wheat plot 2, to show that a gain of more that 2 bushels to the acre must be attributed to green manuring, this being the difference between the yields of wheat on plots 7 and 8 in favor of the plot on which peas had been turned under.

If the turning under of a leguminous green-manure crop under the conditions of this experiment was markedly beneficial it might be expected that the effect would be cumulative and that the later years of a rotation would show much better yields on such plots than on others not having received a leguminous green-manure crop. It will be interesting in this connection to compare the yields from plots 4, 7, 8, 9, 11, and 12, all of which were carried through the four courses. These yields are given in Table 13.

It appears from this table that the average yield for the 16 years was smaller on the plot on which peas were grown or were turned under than on those on which millet or rape were grown. Further, during the last of the four courses the yield from the plots on which

peas were grown and turned under was less than that on which millet was grown and removed and no more than that on which rape was grown. During 1906, the sixteenth year of this experiment, and after four crops of peas had been turned under on plot 8, the yield was 3.4 bushels less than on the adjoining plot 9, from which a crop of millet had been removed every time a crop of peas was plowed under on plot 7. In considering the value of a legume under the conditions of the experiment the above facts must be borne in mind as well as the fact that the yields of wheat were larger when the peas were turned under than when they were removed.

TABLE 13.—*Average yields of wheat in bushels per acre in each of four courses of various rotations at the North Dakota station.*

| Cropping. | 1st course, 1892–95. | 2d course, 1896–99. | 3d course, 1900–03. | 4th course, 1904–06. | Average. |
|---|---|---|---|---|---|
| Fallow one year, wheat 3 years | 19.68 | 25.18 | 26.92 | 15.17 | 21.73 |
| Peas 1 year, cut, wheat 3 years | 20.30 | 21.78 | 16.58 | 10.90 | 17.39 |
| Peas 1 year, turned under, wheat 3 years | 18.35 | 20.26 | 22.09 | 12.82 | 18.34 |
| Millet 1 year, cut, wheat 3 years | 19.98 | 23.52 | 21.84 | 14.55 | 19.97 |
| Millet 1 year, turned under, wheat 3 years | 20.11 | 21.86 | 24.03 | 16.07 | 20.27 |
| Rape 1 year, wheat 3 years | 23.95 | 22.11 | 19.78 | 12.35 | 19.55 |

Green-manure tests have been conducted at the Edgeley, Dickinson, and Williston substations from 1907 to 1914, wheat and oats being grown in 4-year rotation of grain, corn, grain, green manure (Bul. 110). In another rotation fallow was substituted for the green manure. Spring and winter rye, peas, and sweet clover were used as green-manure crops expect that at Williston no sweet clover was used. The table of yields (p. 187) shows that no effect was apparently produced by plowing under green manures; this is also the conclusion expressed by the authors (p. 186). Wheat returned larger yields after rye turned under than after peas turned under (Third Annual Report, Dickinson Sub-experiment Station, 1910) and the following year oats on the same land also yielded better on the rye plot than on the pea plot.

At the Edgeley substation wheat was grown for six years following various crops; the average yields for the period are given in the Tenth Annual Report of the Edgeley Sub-experiment Station, 1912. The highest wheat yields followed corn and fallow, while the yield after peas and rye had been turned under was about 2 bushels less.

SOUTH DAKOTA.

Twenty-two different rotations were started in 1897 and these are reported in Bulletin 79, where detailed analyses of results will be found. The author concludes that the best average yields of wheat have followed corn, roots, and fallow; that following peas and vetch the yields have been slightly under the general average and that the lowest yields followed oats or continuous wheat. In a discussion of each rotation the author maintains, however (page 31), that turning under peas has been beneficial, but the argument seems forced, and the author himself has doubts in regard to the validity of the evidence (p. 32).

The same rotations are discussed in Bulletin 98, in which the crops harvested during eight years are considered. The author's conclusions may be quoted in part:

> The best average yields of wheat have been obtained in those rotations where that crop follows either corn or potatoes. Following these crops in the order of their merit as a preparation for the growth of wheat comes summer fallow, millet, vetch, peas, wheat and oats.
>
> Plowing under peas for green manure has not as yet shown any benefits over a summer fallow.
>
> At the end of eight years land that has grown wheat and corn alternately is producing better crops of wheat, of both straw and grain, than is similar land upon which wheat has been alternated with vetch and with summer fallow.

A number of varieties of barley were grown in 1910 on corn and on turned alfalfa sod (Bul. 124). The average yield was less than a half bushel more on the alfalfa sod than on the corn land.

WYOMING.

Land that had been five years in alfalfa was broken up and wheat, oats, and potatoes were planted on this and on adjoining land that had been tilled. Half of each plot of wheat, oats, and potatoes in 1899 was on old alfalfa and half on tilled land. The yields were in each case much better on the alfalfa sod; this was especially the case with oats, the yield of which was three times as large on the alfalfa sod as on the tilled land (Bul. No. 44).

SUMMARY.

In this section various legumes as well as rye and millet have been tried as green manure, and wheat and corn have been the chief indicator crops.

With the exception of the experiments reported from California

the record shows little, if any, benefit from turning under green-manure crops. There are isolated cases of increased crops, as in Kansas after sweet clover and cowpeas, but the extensive tests at Brandon and Indian Head in Canada, in North and South Dakota, and in part in Kansas and Nebraska show as good or better yields after fallow as after a green crop turned under. This is true not only of the grain immediately following the green manure, but is generally true for the entire period of the test, which in some cases continued for ten years. Besides fallow, a hoed crop appeared to be a better preparation for grain than the turning under of a green crop or the stubble of a legume crop. The growing of clover and timothy for two years gave positive results in Kansas, the grain crop being materially increased, especially in the later years of the rotation.

In many cases rye and millet turned under gave as good results as the turning under of field peas. The turning under of an alfalfa sod was generally followed by larger crops than were taken from adjacent land on which alfalfa had not been grown,

In California the turning under of green crops in spring resulted in better grain yields the following winter than were taken from fallowed land. In this case, however, there was really a summer fallow succeeding the turning under of the green manure. Here, too, rye gave better results than the legume.

Under irrigation in southern California the legumes appear to have fully filled the place of nitrogen gatherers generally assigned them, since the yields following legumes were larger than those after barley, even when reinforced with considerable applications of nitrates.

## Addenda.

In part 1 of this article, add the following under the heading "North Carolina" on page 72:

In a test conducted at the Tarboro test farm in 1901 it was found that the yields of corn following soy beans and velvet beans turned under was greater than where commercial nitrogen had been added. The yield after velvet beans was particularly good. (Board of Agriculture, vol. 23, no. 1, p. 23.)

## General Summary.

While most of the experimental work in the South and Atlantic Coast sections is open to serious objection when critically considered, a body of evidence remains, cumulative in its effect, to show that leguminous green-manure crops increase the yields of following crops under the conditions prevailing in those sections. There is no ade-

quate evidence to show whether or not this result would also be obtained by the use of nonleguminous green-manure crops. The results at the Rhode Island station point at least to the possibility that under some conditions the roots of a grass sod may be quite as efficient as a legume. Some of the Michigan and Minnesota work might be interpreted in the same way, though there is little evidence to this effect at present. At the Maryland station better yields were produced after rye than after crimson clover.

In a general way, it has been shown that care must be exercised in the turning under of the green-manure crop to avoid injury, but the relation between different methods of treatment and the various following crops remains to be studied further.

While it has been shown that there is a marked residual value to a green-manure crop, the value of this has not been worked out. In fact, the subject has been touched on at but one station and that inadequately. This residual value of various green-manure crops for the different succeeding crops in the rotation is a promising field, awaiting agronomic research.

In the north there is convincing evidence of the value of red clover as a green-manure crop under the conditions prevailing in the Provinces of Ontario and Nova Scotia. The fact that there is a pronounced residual value has also been brought out. Farther west in our Ohio and Mississippi valleys evidence of the value of green manure crops is mostly wanting. Contrary to the Canadian results, there is even some evidence against concluding that it has value and much of the work is unsatisfactory. As a rotation crop, clover has been shown to be beneficial, but there is need for more exact work to show, if possible, how much of this benefit is due to the clover as a legume and how much must be ascribed to the growing of crops in a rotation. The question is not one of the benefit to be derived from a rotation; that is well established. The important matter is whether a legume in such a rotation gives better results than would be obtained from growing a crop of similar habit but a nonlegume, as timothy. On this phase of the question the record throws no light.

While in Illinois part of the evidence is negative, this becomes even more the case in the Northwest, where there is no adequate evidence to show that a leguminous crop is better than a nonlegume as green manure, nor even that turning under a green-manure crop results in better yields than summer fallow. It does not appear that any serious effort has been made to determine whether this result is due to the possible fact that the soils of our west and northwest

still contain a sufficient supply of humus, or to the different moisture conditions prevailing.

It is a fact of some interest to observe that, excluding the region west of the Rocky Mountains, the value of a legume as green manure, as shown by the published work of the American experiment stations, decreases roughly from southeast to northwest. There can be no doubt of the value of cowpeas and similar crops in the South, nor of crimson and red clover in the East and Northeast, but this feeling of assurance is changed to one of uncertainty as the records from the Ohio and Mississippi valleys are studied and finally to the conviction that in the Dakotas and in the Canadian Northwest the conditions do not warrant the use of a leguminous green-manure crop.

### Tabular Summary of Literature.

Table 14 contains a summary of the references to station bulletins, circulars, and annual reports in which the effect of the preceding crop on the growth or yield of succeeding crops is reported. References to the effect of green manures on certain minor crops are given in a footnote to the table.

### Bibliography.

#### ALABAMA.

Newman, W. H.
1890. Field experiments with cotton, peas, Melilotus and corn. Canebrake Sta. Bul. 7.
Duggar, J. F., and Richeson, J. M.
1907. Experiments with cotton and corn in 1906. Canebrake Sta. Bul. 24.
Stevens, F. D.
1908. Experiments with cotton and oats in 1907. Canebrake Sta. Bul. 25.
1909. Fertilizer tests with cotton. Cover crops. Alfalfa yields. Canebrake Sta. Bul. 26.
1910. Agricultural value of nitrogenous materials for cotton on the Houston clays, as determined by field trials. Residual effect of cover crops. Alfalfa—yields and effect as a means of restoring fertility. Canebrake Sta. Bul. 27.
Duggar, J. F.
1897. Experiments with oats. Ala. Agr. Expt. Sta. Bul. 95.
1901. Corn culture. Bul. 111.
1901. The cowpea and the velvet bean as fertilizers. Bul. 120.
1903. Agr. Expt. Sta. 16th Ann. Rpt.
1905. Agr. Expt. Sta. 18th Ann. Rpt.
1905. Corn culture. Bul. 134.
1909. Experiments with oats. Bul. 137.
1909. Crimson clover. Bul. 147.

TABLE 14.—*Summary of references to station bulletins, circulars, and annual reports in which the effect of the preceding crop on the growth or yield of succeeding crops is reported.*[a]

(Numbers refer to bulletin s unless otherwise stated.)

| Preceding crop and station. | References to the effect of the crop named in the left-hand column on the growth of—[b] | | | | |
|---|---|---|---|---|---|
| | Corn. | Cotton. | Oats. | Potatoes. | Wheat. |
| Alfalfa. | | | | | |
| Ala. | | Cane. 26, 27 | | | |
| Canada | 165 | | | | 165, Rpts. 1899, 1908, '09 |
| Colo. | | | | 57, 117 | |
| Nebr. | | | 155 | | |
| N. Y. | 339 | | 339 | | |
| Wyo. | | | 44 | 44 | 44 |
| Alfalfa and alsike clover. | | | | | |
| Canada | Rpt. 1898 | | | | Rpt. 1898–1900, 1902–6, 1908–9, 1911 |
| Barley. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | |
| Kans. | 147 | | | | 144 |
| Nebr. | | | 155 | | |
| N. Dak. | | | | | 11 |
| Beans and rye. | | | | | |
| Mich. | Rpt. 1911 | | | Rpt. 1911 | Rpt. 1911 |
| Beans, Horse. | | | | | |
| Cal. | | | | | 211, 270 |
| Beans, Soy. | | | | | |
| Ala. | | Cane. 24 | 137 | | |
| Ark. | 58 | 58 | 66 | | 62 |
| Canada | | | | | Rpt. 1900, '02–06 |
| Kans. | 147, 160 | | | | 144, 160 |
| Mass. | | | Rpt. 1903 | Rpt. 1903 | |
| N. J. | 289 | | 289, Rpt. 1888 | | 281 |

| | | | | | |
|---|---|---|---|---|---|
| Beans, Soy. | | | | | |
| N. C. | Bd. Agr., Vol. 23 | | | | |
| Ohio | | | | | 275 |
| Beans, Velvet. | | | | | |
| Ala. | 111, 120, 134 | 111, 120 | 95, 104, 20, 37 | | 120 |
| Ark. | | 58 | 66 | | 62 |
| N. C. | Bd. Agr., Vol. 23 | | | | |
| Beggar weed. | | | | | |
| Ala. | 111, 120, 134 | | | | |
| Ark. | | | 66 | | 62 |
| Buckwheat. | | | | | |
| Ark. | | | 66 | | |
| Canada | | | | | Rpt. 1899 |
| Ill. | 99 | | 99 | | |
| Carrots. | | | | | |
| Canada | | | | Rpt. 1899 | |
| Chufas. | | | | | |
| Ala. | | | 137 | | |
| Clover, Alsike. | | | | | |
| Conn. | | | | Rpt. 1899–1900 | |
| R. I. | 76, 167 | | | | |
| Clover, Bur. | | | | | |
| Ala. | | Cane. 25, 26, 27 | | | |
| Cal. | | | | | 270 |
| Clover, Crimson. | | | | | |
| Ala. | | 147, Cane. 25, 26, 27 | | | |
| Del. | Rpt. 1892 | | | | |
| Md. | 46, 68, 114 | | | 31, 38 | |
| N. J. | 288, 289, Rpt. 1912–13 | | 289, Rpt. 1912–13 | 289 | 288, Rpt. 1914 |
| R. I. | 133 | | | | |
| Clover, Mammoth. | | | | | |
| Canada | Rpt. 1898 | | | | Rpts. 1898, 1899 |
| Clover, Red. | | | | | |
| Ala. | | Cane. 26, 27 | Cane. 25 | | |

TABLE 14.—*Continued.*

| Preceding crop and station. | References to the effect of the crop named in the left-hand column on the growth of— | | | | |
|---|---|---|---|---|---|
| | Corn. | Cotton. | Oats. | Potatoes. | Wheat. |
| Clover, Red, | | | | | |
| Canada | Rpts. 1898, 1901, '02, '03, '04 | | 40, Rpts. 1899, 1901–03, '05, '06, '08, '10 | Rpts. 1899, 1900, '01, '02, '03, '04 | Rpts. 1898, '99, 1900, '02–'06, '08, '09, '11 |
| Ill. | 31, 42, 96, 125 | | 31, 42, 96, 125 | | |
| Ind. | 27, 64, 88, 114 | | 27, 64, 88, 114 | | 27, 64, 88, 114 |
| Iowa | 167, R. 6, R. 25 | | 167, R. 6 | | |
| Mass. | | | | Rpts. 1900, '03 | |
| Mich. | Rpt. 1911 | | Rpt. 1911 | | Rpt. 1911 |
| Minn. | 40, 109 | | 40, 109 | | 40, 109 |
| N. Dak. | | | | | 23, 39 |
| Ohio | 144, 282, C. 120 | | C. 120 | C. 40, C. 79 | 53, 168, C. 40, C. 79, C. 120 |
| R. I. | | | | Rpt. 1897 | 144 |
| Wis. | | | | 147 | |
| Clover, Red or Mammoth, and Timothy mixed. | | | | | |
| Minn. | | | 40, 109 | | 40, 109 |
| N. Dak. | 40, 109 | | | | 23, 39 |
| Clover, Sweet. | | | | | |
| Ala. | | Cane. 7 (1890) | 10 | | |
| Canada | | | | | Rpt. 1898, '99 |
| Kans. | A. C. Rpt. 1915 | | | | A. C. Rpt. 1915 |
| Ohio | | | | | 42 |
| Tenn. | 109 | | | | |
| Clover, Sweet, Yellow Annual. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | |
| Clover, White. | | | | | |
| Ala. | | Cane. 26, 27 | Cane. 25 | | |
| Corn. | | | | | |
| Ala. | 134 | | 137 | | |
| Ark. | 46 | | 66 | | |
| Canada | | | | | Rpt. 1893 |

| | | | | | |
|---|---|---|---|---|---|
| Corn. | | | | | |
| Kans. | 147 | ... | ... | ... | 144 |
| Mich. | Rpt. 1911 | ... | Rpt. 1911 | ... | Rpt. 1911 |
| Nebr. | ... | ... | 155 | ... | ... |
| N. Dak. | ... | ... | ... | ... | 11, 100, Rpt. '12 |
| S. Dak. | ... | ... | ... | ... | 79, 98 |
| R. I. | 113 | ... | ... | Rpt. 1897 | ... |
| Corn and cowpeas. | | | | | |
| Kans. | 147 | ... | ... | ... | ... |
| Corn, Kafir. | | | | | |
| Kans. | 147 | ... | ... | ... | 144 |
| Cotton. | | | | | |
| Ala. | 120 | 120, Cane, 27 | ... | ... | ... |
| Ark. | 46, 58 | ... | ... | ... | ... |
| Cowpeas. | | | | | |
| Ala. | 7 (1887), 111, 120, 134, W. A. Rpt. 1903 | 120, W. A. Rpt. 1903, Cane. 7 (1890), 24, 27 | 95, 104, 120, 137 | ... | 120 |
| Ark. | 18, 22, 27, 46, 58 | 18, 22, 27, 46, 58 | 66, 70 | ... | 62, 77 |
| Ga. | ... | 27 | ... | ... | ... |
| Ill. | 99, 115, 125; C. 96 and 97 | ... | ... | ... | 88, 115, 125; C. 97, SR3, 11, 12, 14 |
| Iowa | R6, 161 | ... | R6 | ... | ... |
| Kans. | 160, A. C. Rpt. 1915 | ... | ... | ... | 160, 175 |
| Md. | ... | ... | ... | ... | 110 |
| Miss. | ... | 101 | ... | ... | ... |
| Mo. | 83, 84, 119, 126, 127, 128, 129, 130 | ... | ... | ... | 83, 84, 119, 126, 127, 128, 129, 130, 131 |
| N. J. | 289 | ... | 289 | 289 | Rpt. 1912 |
| N. C. | ... | ... | ... | ... | 72, 77 |
| Tenn. | 102 | ... | ... | ... | 90, 96 |
| Emmer. | | | | | |
| Kans. | 147 | ... | ... | ... | ... |

TABLE 14.—*Continued.*

| Preceding crop and station. | References to the effect of the crop named in the left-hand column on the growth of— | | | | |
|---|---|---|---|---|---|
| | Corn. | Cotton. | Oats. | Potatoes. | Wheat. |
| Fallow. | | | | | |
| Canada | | | Rpt. 1909 | | Rpt. 1893, '98, '99, 1902, '04, '05, '08, '09 |
| Cal. | | | | | 211, 270 |
| Mich. | Rpt. 1911 | | Rpt. 1911 | | Rpt. 1911 |
| N. Dak. | | | 110 | | 11, 100, Rpt. 1912 |
| S. Dak. | | | | | 79, 98 |
| Fenugreek. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | 270 |
| Flax. | | | | | |
| Kans. | 147 | | | | 144 |
| Grass, Brome. | | | | | |
| Canada | | | 40, Rpt. 1899 | | Rpt. 1899 |
| Minn. | 40, 109 | | 40, 109 | | 40, 109 |
| Nebr. | | | 155 | | |
| Grass, Crab. | | | | | |
| Ala. | 120 | | 95, 104, 137 | | |
| N. C. | | | | | 72, 77 |
| Grass, Orchard. | | | | | |
| Mich. | Rpt. 1911 | | Rpt. 1911 | | Rpt. 1911 |
| Grass, Redtop. | | | | | |
| Ala. C. | | 27 | | | |
| Grass, Western Rye. | | | | | |
| Canada | | | | | Rpt. 1911 |
| Lentils. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | |
| Mangels. | | | | | |
| N. Dak. | | | | | 11 |

| | | | | | |
|---|---|---|---|---|---|
| Millet turned under. | | | | | |
| Ala. | | | 95 | | |
| Kans. | | | | | 144 |
| N. Dak. | | | | | 11, 100 |
| Millet stubble. | | | | | |
| Ala. | 120 | | 95, 104, 137 | | |
| Kans. | 147 | | | | |
| S. Dak. | | | | | 98 |
| Oats. | | | | | |
| Ala. | 111 | 147, Cane. 27 | | | |
| Ark. | | | 66, 70 | | |
| Canada | | | Rpt. 1909 | | Rpts. 1893, '99, 1902, '08, '09 |
| Kans. | 147 | | | | 144 |
| Nebr. | | | 155 | | |
| N. Dak. | | | | | 11 |
| S. Dak. | | | | | 98 |
| Peanuts. | | | | | |
| Ala. | | | 137 | | |
| Ark. | 46 | | | | |
| N. C. | Bd. Agr., Vol. 23 | | | | |
| Peas, Canada Field. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | 211, 270 |
| Canada | | | | | Rpts. 1893, '99, 1900, '02–'06, '08, '09 |
| Nebr. | | | 155 | | |
| N. Dak. | | | 110 | | 11, 100, 110, Rpt. 1910, '12 |
| S. Dak. | | | | | 79, 98 |
| Peas, Tangier. | | | | | |
| Cal. | Rpt. 1913 | | | Rpt. 1913 | |
| Potatoes. | | | | | |
| Kans. | 147 | | | | |
| S. Dak. | | | | | 98 |

TABLE 14.—*Concluded.*

| Preceding crop and station. | References to the effect of the crop named in the left-hand column on the growth of— | | | | |
|---|---|---|---|---|---|
| | Corn. | Cotton. | Oats. | Potatoes. | Wheat. |
| Wheat. | | | | | |
| N. Dak. | ....... | ....... | ....... | ....... | 11, 100, Rpt. 1912 |
| S. Dak. | ....... | ....... | ....... | ....... | 79, 98 |
| Wheat and cowpeas. | | | | | |
| Kans. | 147 | ....... | ....... | ....... | ....... |

[a] The following abbreviations are used in the table: A. C. Rpt. = Allen Co. (Kans.) Farm Bureau Report; C. = Circular; R. = Research (Iowa Research Bul.); Rpt. = Report (usually, the annual report of the experiment station); S. R. = Soil report (of the Illinois station); W. A. = West Alabama report; Cane. = Alabama Canebrake Station.

Unless otherwise designated, the references are to experiment station bulletins.

[b] References to the effect of the previous crop on crops not mentioned in the table are as follows:

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# IMPROVED TECHNIQUE IN PREVENTING ACCESS OF STRAY POLLEN.[1]

ADOLPH WALLER AND L. E. THATCHER.

## PREVIOUS RESEARCH.

The difficulties that have vexed the plant breeder trying to protect a pedigreed culture from stray pollen are as old, one might well say, as the recognition of the significance of pollen itself by Camerarius in 1694. Darwin wrote about his fears that small insects might get through the nets he was using to protect his flowers. Recently Pearl and Surface[2] built cages around bean plants to protect them from bumble bees carrying pollen, while Shaw,[3] on the other hand, made use of thrips (*Thysanoptera* sp.) to insure cross pollination. It would be a difficult and profitless task to assemble the references concerning means of guarding against adventitious pollen, for although everyone is aware of the possibility of its access it is only rarely that one finds mention of measures taken to prevent chance crossing. Information on methods of pollination is scarce also, though papers on corn by Collins[4] and Gernert[5] were published several years ago. If descriptions of all the time-saving methods in pollination and all the devices used to protect the elite plants could be gathered so as to be accessible it would make interesting and instructive reading It is to be hoped that the files of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY will become the disseminator of as much of this information as is related to our important crop plants.

In Hillman's[6] excellent compilation of the nature and scope of the plant-breeding work in Germany, photographs are given of a number

[1] Contribution from the Farm Crops Laboratory, Ohio State University. Received for publication January 26, 1917.

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[3] Shaw, H. B. Thrips as pollinators of beet flowers. U. S. Dept. Agr. Bul. 104. 1914.

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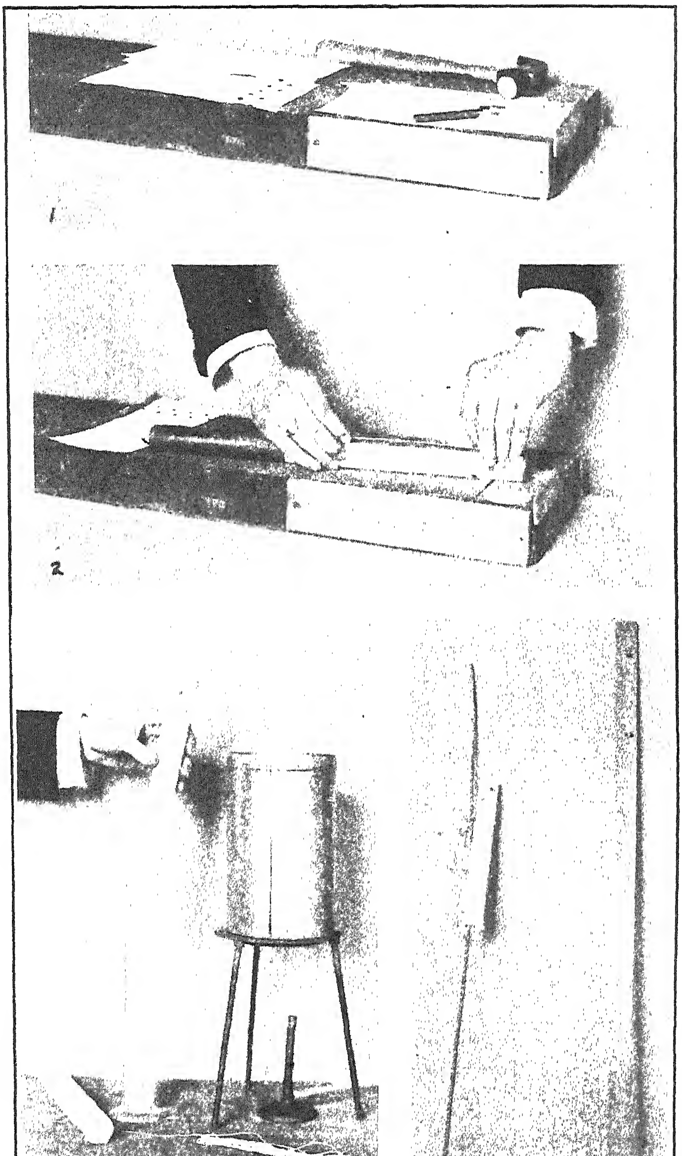
of different methods employed to prevent promiscuous cross-pollination in many kinds of plants. Muslin cages surrounding plots, caps and bags covering individual plants, and glass tubes placed over the heads of selected wheat plants are some of the devices pictured. It was the illustration showing the glass tubes that suggested another means of preventing accidental crossing in the small grains. The waxed paper capsule was chosen not as a mere substitute but as an improvement upon the tubes destined for wider uses than with the small grains only.

## Materials and Methods.

During the spring and summer of 1916, the writers used the method described below with such success that they feel warranted in offering it at this time to others in crop improvement work, although slight refinements and changes may be made during the next few years. Since these are no more than anyone employed in similar investigations is likely to try out for himself, little hesitancy is felt in narrating what has been learned to date. It is sincerely hoped that other experimenters will give the suggestion contained here a thorough trial, returning such criticism and observations as are derived from their results.

The ideal device for protecting the floral organs or an inflorescence from adventitious pollen would have the following qualifications: It must effectually exclude stray pollen; the size and shape must be readily adaptable to a variety of growth habits of different plants; it must be sufficiently substantial to withstand the destructive action of the weather, during at least the blooming and often during the ripening period of the plant; to permit the escape of excess moisture from within, it must be freely ventilated; it must be impervious to water from the outside; it should guard against accumulation of heat from the sun's rays; the least possible weight is a desideratum, but in addition an easy means of fastening the protective device to a support ought to be at hand; it should be convenient, so that without loss of time it may be applied or removed. In short, while affording protection, it should offer as little interference as possible to the normal plant processes. Along with all the desirable features, it must be inexpensive.

The tube or capsule which has been found to fill most nearly these specifications is a simple affair made from white ledger paper of fairly firm texture, sheets 17 by 22 inches in size and running 28 sheets to the pound. No elaborate equipment or special skill is required for its manufacture. The size which can be used successfully on the




Method of making capsules to prevent cross pollination: (1) Equipment for punching holes in capsule; (2) rolling gummed strip to form tube; (3) dipping the capsule in the wax bath; (4) completed capsule tied to bamboo stick, and lath to which stick is fastened.

small grains is made by cutting the paper into strips 12 by 30 centimeters. These are then placed several sheets thick on a block of soft wood standing with the grain end up. A row of holes 7 millimeters in diameter and 2 centimeters apart is punched across the sheets 4 centimeters from one end by means of an ordinary leather punch, as shown in Plate 3, fig. 1. A strip 15 mm. wide along one side of a sheet is then gummed and the paper rolled on a cylinder of wood about 35 millimeters in diameter. This forms a paper tube, such as is shown in Plate 3, fig. 2. The tube is then slipped along the wood form, punched end first, until about 1 centimeter extends beyond the form. The edge is then crimped over, the end gummed, and a disk of gummed paper slightly larger than the tube is applied, forming a cap. Having made sure that the adhesion is perfect, the form is withdrawn. The capsule is then ready to receive the bath of wax made as described below. The wax is most conveniently handled in a tall glass cylinder the diameter of which is only slightly larger than the paper capsule, as shown in Plate 3, fig. 3. It may be kept in liquid form by immersing the cylinder in a water bath. The capsule is dipped about half its length, withdrawn slowly, reversed, and when cool, dipped the rest of the way.

Strong wrapping twine that has been waxed in the same mixture is cut into convenient lengths, about 50 cm., and one of these lengths is tied about 6 cm. from each end of the capsule. These weatherproofed strings serve to fasten the capsule securely to its support. A loose wad of absorbent cotton is pushed up into the capsule until just below the ventilating holes, making the capsule ready for use in the field.

The support for the capsule is best made as follows: An ordinary plastering lath is sharpened at one end. To the other end a piece of slender bamboo not over 1 centimeter in diameter at the base is fastened with small staples. The support is driven firmly into the ground by pounding on the end of the lath to which the bamboo is fastened. The flat lath gives added stability, as it is not likely to be twisted and lifted by the wind as would be the case with a more nearly round or square support. It is firm but flexible and not easily broken or loosened by storms. The length of the support will of necessity be adjusted to the height of the plant. It is well to have the bamboo somewhat taller than the stem of the plant at the time of encapsuling to allow for some elongation up to the time of ripening. The mounted capsule is shown in Plate 3, fig. 4.

Having prepared the inflorescence, a capsule should be slipped over it and tied to the support. A loose plug of cotton is carefully

inserted in the lower end to exclude pollen that might be blown up into the capsule or brought in by insects. In tying the capsule to the support, the twine should be wrapped around the bamboo stick at least twice to prevent slipping and tied in a bow knot. The proper tag or label can be inclosed within the capsule. Usually it is advisable to fasten the stem or branch to the support in two places by means of a waxed cord tied rather loosely. It is an easy matter to remove the capsule at any time for examination or for any plant-breeding operation. After fertilization has taken place and stray pollen is no longer dangerous, the cotton plugs may be removed. The capsule then affords excellent protection against damage by birds, storms, etc., and is conspicuous enough to be found easily in the field at any time. Grain which has ripened in these capsules is of prime quality.

The most satisfactory preparation for waxing the capsules is composed of the following:

| | |
|---|---|
| Pure white beeswax .................... | 800 grams. |
| Stearic acid ............................ | 200 grams. |

This wax gives body to the capsule, making it quite firm and resilient, yet is not softened materially by the heat of the sun, as its melting point is 67° C. Paraffin with a melting point of 57° C. has not given good results,

The capsules have been used with much satisfaction in selfing wheat (in which, in the authors' opinion, more crossing normally takes place than is generally supposed), rye, timothy, orchard grass, meadow foxtail, and Italian rye grass, and in hybridizing wheat, oats, barley, alfalfa, and soybeans. The usefulness of the capsules is not limited to the plants mentioned in the present discussion. A change in the size and shape of the forms upon which the tubes are rolled and in the means of supporting the capsules in position will easily adapt them for use on shrubs and small trees as well as on a wide range of herbaceous plants.

It sometimes becomes necessary to replace the cotton in the capsules after a hard rain, as water may gain access through the ventilating holes and force them out. A method of construction to overcome this is now under consideration.

## Summary.

The advantages of these reinforced capsules over other devices for guarding against undesirable cross pollination may be summarized as follows:

Glass tubes of the same general form as the capsules herein described are heavy, costly, fragile, and collect moisture on the inside which will frequently spoil the pollen and prevent fertilization or favor later the growth of molds. When exposed to the direct rays of the sun, the temperature within the glass tubes becomes dangerously high. The translucent paper capsules hinder but little the continuance of the normal plant processes and are cheap, light, and durable.

Paper bags, wisps of cotton, and tissue paper coverings are not substantial. After the slightest precipitation or even after heavy dews they are likely to be soggy and require replacement.

No other methods known to the writers will protect against the pollen thrips or other small insects that sometimes render pedigreed cultures worthless. At the same time some of the moisture given off from the enclosed portion of the plant is absorbed by the cotton.

The isolation of the inflorescences in the paper capsules obviates the necessity of scattering plats of cultures in places that are frequently unfavorable for the growth of plants and are also inconvenient to visit and care for. The capsule likewise makes possible the isolation of flowers borne on shrubs and trees that could not be separated a sufficient distance from each other to insure freedom from undesirable pollen.

The large degree of protection which the capsule affords to the developing and ripened fruit is also a distinct advantage.

Ohio State University,
Columbus, Ohio.

# AGRONOMIC AFFAIRS.

## NEW BOOKS.

*The Small Grains.* By MARK ALFRED CARLETON, Cerealist, Bureau of Plant Industry, U. S. Department of Agriculture. The Macmillan Company (New York), 1916. 8vo. Pages 699; figs. 183; bibliography of more than 500 titles.

The material in this book, which is intended for collegiate use, is presented under four main divisions:—I, Cereal Plants; II, Cereal Environment; III, Cereal Crops; and IV, Buckwheat and Rice.

The book opens with a discussion of the form and structure of the small grains, with original figures showing the anatomical structure of the wheat seed, culm, and leaf blade. A discussion of plant growth and nutrition follows. The author says that a study of these chapters may be omitted by those students who have had good training in plant physiology.

The origin, classification, varieties, and regional adaptation of wheat are then taken up. A fairly complete list is given of important United States varieties of wheat, with an extensive list of world varieties. These are listed under the eight commonly recognized agronomic groups. The United States and Canada are then subdivided into ten wheat districts and the important varieties for each district are given. Statements of the needs of these various districts as to improved sorts are of special value. A short discussion of the wheat distribution in other countries includes a statement of the particular value of the varietal groups grown in these various regions. Oats, barley and rye are discussed in essentially the same manner as has been outlined for wheat.

Introduction, selection, and hybridization are discussed under the heading of "Improvement of the Small Grains." A description of the original introduction and subsequent improvement of many of our important cereal varieties is an interesting feature. Improvement by selection is presented under the headings of (1) sorting and roguing, (2) mass selection, and (3) pure line selection. The essential differences and relative value of these three methods of work are discussed. A more detailed presentation of the use of the seed plat would add materially to this chapter. The selection of enough seed for a seed plat of 1 to 2 acres would be quite a task. The selection of a con-

siderable number of typical heads at harvest would probably accomplish the same result. Neither does there seem to be any particular value in the plan of growing enough seed in the special seed plat for the entire acreage.

The two methods of pure-line selection given by the author are the centgener and row plans. These methods as now practiced differ only in the minor particular of shape of plot. A description of the rod-row method now so widely used in preliminary breeding and varietal tests would be of value.

Under "Hybridization" the author describes the application of Mendel's law to inheritance and subsequent improvement in small grains. The behavior of the first, second, and third generations of a cross is given when the parents differ by a single contrasted character. The author says, "When the parents differ in two or more characters there is effected a recombination of characters of much value in breeding." An illustration of the behavior of crosses differing in two or more characters would make the matter much clearer. A brief description of the general class of results obtained in crosses between types which differ in important quantitative characters as height of culm, size of seed, and yield would be of interest even though these characters do not give as clear-cut segregation as is often obtained for qualitative characters.

The author describes a considerable number of valuable economic varieties which have been produced by the hybridization method.

Part II discusses cereal environment under the headings, Soil Relations, Climatic Relations, and Cereal Adaptation and Association. The important cereal regions of Europe and Asia are considered from the standpoint of the nature of the soil. This is followed by a similar presentation of the soil of American cereal growing regions. This presentation considers mechanical and chemical constituents of the soil of the cereal regions, particular attention being paid to a discussion of moisture relations and alkali resistance.

A summarized statement is given of the general climatic features common to all cereal-growing regions, followed by a more detailed discussion of the differences between the different important areas. Especial emphasis is placed upon moisture, sunlight, and temperature.

Under "Adaptation" the important natural cereal regions of the world and the main groups specially adapted to these regions are discussed. Acclimatization, change of seed, and effects of environment are presented under the heading of "Environment." A discussion of the cereal crops from the ecological standpoint is given under the heading of The Cereal Plant Community.

Instead of discussing methods of culture and handling of the crops in connection with the initial treatment of each crop, the author deals with this question for all crops in a separate section of his book. This would seem to be a commendable departure. As there are few cultural details which apply exclusively to any one of the small grain crops, much repetition is avoided by this method of treatment. This discussion appears in Part III of the book. The subject matter is presented under the headings, "Soil Treatment," "Growing the Crops," and "Gathering the Crop." Very full discussion is given and experimental results are generously quoted.

The greater portion of the discussion on uses of cereals naturally is devoted to wheat flour. This discussion includes a very good description of the milling process, and a sketch showing the various steps in the process is presented. Grades of flour are described with reference both to the step in the milling process from which they are obtained and the kind of wheat used in their production. The edible pastes made from wheat are briefly discussed. The uses of cereals as grain and forage for live stock, and their uses in the preparation of breakfast foods and in malting and distilling are also dealt with.

Under the heading, "Cereals in Commerce," the author discusses various phases of grain marketing. The facilities for receiving the grain locally and at the terminal markets are described, with a discussion of grain grading and inspection. A detailed description of each of the market grades within each of the commercial classes of grain might well have been included.

A few brief but pointed details regarding exchange operation are very appropriately given. The knowledge of such operations as hedging and selling for future delivery is not generally possessed by those who are not large dealers in grain or who otherwise come into contact with the operations of the large grain exchanges. The lack of such knowledge is responsible for much unjustifiable suspicion of the operations of the organized grain trade.

Buckwheat and rice are taken up separately as Part IV, as these crops are botanically different from the four important cereals previously discussed. The same general plan of procedure is used as has been already outlined for wheat, barley, oats, and rye.

The book is written in a very clear and interesting manner by a recognized authority in this particular field. It is not only suitable for instructional work in colleges but for the most part is presented so clearly that it deserves a place in every cereal farmer's library.

H. K. Hayes,
P. J. Olson.

## MEMBERSHIP CHANGES.

The membership of the Society as reported in the March issue was 642. Since that time 22 new members have been added and 1 member has resigned, making a net gain of 21 and a total membership at this time of 663. The names and addresses of the new members, together with the name of the member resigned and such changes of address as have come to the notice of the Secretary, as are follows:

### New Members.

Anderson, A. C., Forest Service, Ogden, Utah.
Andrews, Myron E., Warner Dist. Agr. School, Warner, Okla.
Baker, O. E., Farm Management, U. S. Dept. Agr., Washington, D. C.
Bugby, M. O., Canfield, Ohio.
Cocke, R. P., Williamsburg, Va.
Cramer, W. F., Station A, Ames, Iowa.
de Werff, H. A., Agricultural Building, Urbana, Ill.
Dougall, Robert, Macdonald College, Quebec, Canada.
Frank, W. L., 116 E. Eleventh Ave., Columbus, Ohio.
Halverson, W. V., Soils Office, Agr. Expt. Sta., Ames, Iowa.
Hoke, Roy, 318 West St., Stillwater, Okla.
Jackson, J. W., Substation No. 9, Pecos, Texas.
Kenworthy, Chester, Warner Dist. Agr. School, Warner, Okla.
Killough, D. T., Substation No. 5, Temple, Texas.
Kraft, J. H., State Teachers' College, Greeley, Colo.
Langenbeck, Karl, 1625 Hobart St., N. W., Washington, D. C.
Letteer, C. R., San Antonio Expt. Farm, San Antonio, Tex.
Mortimer, George B., College of Agriculture, Madison, Wis.
Nevin, L. B., 2828 Webster St., Berkeley, Cal.
Smith, Howard C., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
Southworth, W., Manitoba Agr. College, Winnipeg, Man., Canada.
Wilkins, F. S., Farm Crops Dept., Iowa State College, Ames, Iowa.

### Member Resigned.

Geo. W. Graves.

### Changes of Address.

Bartlett, H. H., 335 Packard St., Ann Arbor, Mich.
Bliss, S. W., Agr. Expt. Sta., Wooster, Ohio.
Brandon, Joseph F., Akron Field Station, Akron, Colo.
Clark, Chas. F., Box 747, Greeley, Colo.
Craig, C. E., Otwell, Ind.
Emerson, Paul, Maryland State College, College Park, Md.
Jensen, L. N., Box 1214, Amarillo, Tex.
Lyness, W. E., Cheyenne Field Station, Archer, Wyo.
Pridmore, J. C., 616 Rhodes Building, Atlanta, Ga.

## NOTES AND NEWS.

A. B. Beaumont, assistant professor of soil technology at Cornell University, has been appointed associate professor of agronomy and acting head of the agronomy department at the Massachusetts College.

J. A. Foord, head of the division of agriculture at the Massachusetts College, is on a year's leave of absence and is pursuing graduate study at Cornell University.

Arthur Goss, for fourteen years director of the Purdue University station, has resigned to give his entire attention to his farming interests near Vincennes, Ind.

The American Association of Agricultural College Editors will meet at Cornell University, June 28 and 29, 1917.

The third Interstate Cereal Conference will be held in Kansas City, Mo., June 12–14, 1917, in cooperation with the Kansas Agricultural Experiment Station. Station and college workers, grain dealers, millers, and others interested in cereal production and utilization, particularly in Kansas, Missouri, and nearby states, are invited to attend. One of the principal topics for discussion will be the recently announced Federal grades for wheat. Particulars regarding the program may be obtained from the secretary, Chas. E. Chambliss, U. S. Department of Agriculture, Washington, D. C.

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# THE RELATION OF COB TO OTHER EAR CHARACTERS IN CORN.[1]

A. E. Grantham.

## Introduction.

One of the objects of the corn breeder is to produce a type of ear that will carry the maximum quantity of grain. This has led to a critical examination of the physical characters of the ear, with the result that many varieties of corn have been improved to such an extent that they exceed the percentage of grain required by the standard, viz., 80 percent for the commercial grades. The increase in the yield of grain per ear has been accomplished largely by the selection of seed ears with well-filled butts and tips and with deeper kernels of a more desirable shape. The question then arises, "Is the cob, as the carrier of the grain, an important character to be considered in relation to type of ear?" To what extent the characters of the cob are correlated with those of the ear as a whole has not been carefully determined. While some biometrical work has been done upon the corn plant, little attention has been given to the statistical relations of the characters that determine the grain weight of an ear.

It is the object of this paper to present some of the correlations that exist between the cob and other ear characters. The cob itself has been largely overlooked from a mathematical standpoint in corn breeding. This paper attempts to answer some of the questions which may arise concerning the size, weight, and density of cob in

[1] Contribution from the Department of Agronomy, Delaware Agricultural Experiment Station. Presented at the ninth annual meeting of the American Society of Agronomy, November 13, 1916.

relation to yield of grain and to type of kernel, including depth, thickness, and weight. In other words, is the cob of an ear of corn correlated with other desirable characters to such an extent as to warrant careful examination of this part of the ear in selecting seed?

## Methods.

The work reported in this paper was conducted at the Delaware Agricultural Experiment Station from 1910 to 1915. The data given were obtained in the progress of an investigation to determine the relation between the physical characters of ears to the vigor and yield of the plant. In order to get ears for seed that had a given character well developed it was necessary to examine a large number of ears with respect to the number of rows of kernels, weight of ear, depth, thickness, and weight of kernels, and the yield of grain. Owing to the great irregularities and variations in the formation of the butts and tips of ears, it was necessary to take a section of definite length from each ear. This was done by cutting a section 12 centimeters long from the middle portion of the ear, just far enough from the butt to eliminate all irregular kernels. Thus, all of the ears studied were constant with respect to length. By this means the relation of size, shape, and weight of kernel to the other characters could be established in a comparable manner.

In these studies, data were taken from 3,500 ears. Each fall several hundred ears were brought to the heated laboratory where they remained for several weeks until both grain and cob had thoroughly dried. Special attention was given to the dryness of the cob at time of cutting. Tests were made to determine the constancy of the dry weight. As the conformation of the ear is governed largely by the type and regularity of the kernel, care was taken to select for cutting and measurement only those ears which approached the cylindrical in shape and carried straight rows of kernels. The Johnson County White was the variety studied, and it was not difficult to obtain ears of excellent type as to shape and straightness of row. No effort was made to select ears of a given type for cutting; on the contrary, as wide a variation of characters as possible was sought except in shape of ear and straightness of row. Sections were not made from ears under 8 inches in length, owing to the difficulty of obtaining a fully developed cutting. No limit was set upon the variations of the other characters. Some of the extreme variations in certain characters are shown in Plate 4.

The following data were recorded for each section:

Weight of section.
Number of rows.
Circumference of ear.
Thickness of kernel.
Weight of shelled grain.
Weight of cob.
Circumference of cob.
Depth of kernel.
Weight of the individual kernel.
Percentage of cob.
Density of cob.

The weights were recorded in grams and measurements of length and circumference in centimeters. The thickness of kernel was determined by counting the number of kernels (in situ) in 10 centimeters. The average of three readings was taken. The depth of kernel was deduced from the difference in the diameters of cob and ear. The weight of the individual kernel is expressed by the number required to weigh 10 grams. The density of cob is given as a constant derived from the formula, $\frac{\text{Weight}}{\text{Circumference}^2}$. While this does not give the actual density, it furnishes a comparable expression.

### Review of Literature.

While some statistical work has been done upon correlations in corn, the greater part has dealt with the plant as a whole. Other workers have pointed out certain correlations, but the relationships have not been quantitatively determined. Very few statistical studies on the correlation of characters in ear corn have come to the attention of the writer. Apparently no biometrical studies have been made upon the cob in its relation to other characters of the ear. Mention will be made of the published work on this subject, not that it has direct bearing on the studies of the author but to indicate the manner of approach to the general subject of correlations in corn.

Brigham (1896),[2] who made an extensive study of Longfellow flint corn, concluded that an increase in the weight of corn is accompanied by an increase in the number of kernels, weight of cob, and weight of individual kernels. These correlations were not established by statistical methods.

Davenport (1897) found a correlation coefficient of $0.87 \pm 0.005$ between weight of ears in ounces and length of ear in inches, in the

[2] References are to names and dates at the end of the paper.

Leaming variety of corn. He showed that there was a relationship between the circumference and length of ear in inches of $0.47 \pm 0.02$.

Thiel (1899) noted that the greater the diameter of the ear the larger the percentage of cob.

DeVries (1901) found that the size of the kernel decreased as the number of rows per ear increased.

Fruwirth (1904) has called attention to certain correlations he found in Szekler maize. He states that a larger yield of grain is accompanied by a larger number of kernels and by greater weight per individual kernel. It does not appear that these correlations were studied by statistical methods.

Craig (1908) made a number of observations on the correlation of physical characters of the corn plant but did not calculate the variation constants from his data. This, together with the fact that he used only 50 to 100 individuals in each case, renders his results unsatisfactory so far as an exact degree of correlation is concerned.

Ewing (1901) made biometrical studies on the relation of weight of grain to the diameter of the stalk, the length of leaf, the breadth of leaf, the height of the seedlings, the number of internodes, the length of ear at the appearance of silks, the date of the appearance of tassel, the date of appearance of pollen, date of appearance of silks, the duration of the flowering period, and the number of branches in the tassel. The highest correlation found was $0.393 \pm 0.020$, between the weight of grain and the diameter of the stalk. He holds that most of the correlations noted may be "classed as variations in the fluctuating variability of the characters concerned and on further consideration one would put most of them in the class of environmental correlations."

## Correlations.

### I. Circumference of cob and weight of grain.

It is often held by corn breeders that large cobs should be avoided in selecting seed corn. However, it is obvious that a cob with large circumference will carry more grain than a small one, provided the character of the kernel is the same in both cases. The practice of selecting seed ears with cobs of moderate size is probably due to the fact that large ears cure more slowly.

In Table 1 are given the results obtained in studying the relation between the circumference of cob and yield of grain with 3,500 ears of Johnson Co. White corn. The extremes of circumference range from 7 to 15 cm., with a mean of 10.5 cm.; of weight of grain, 105

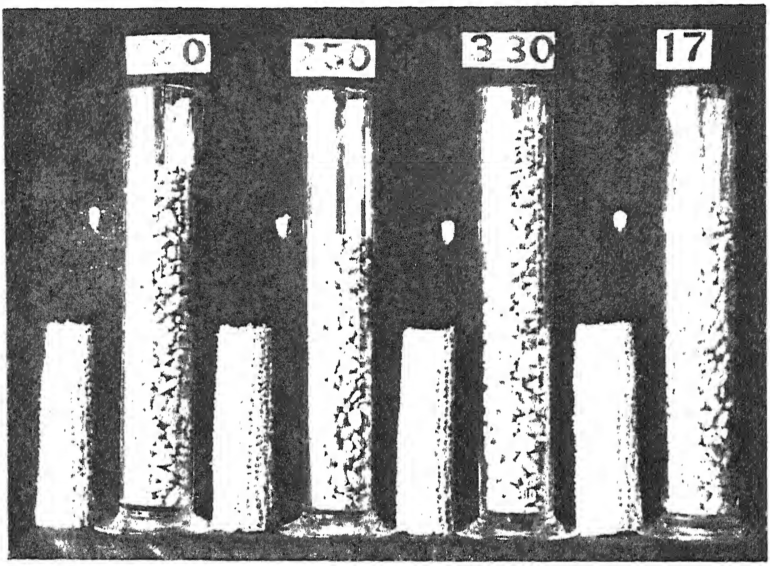


FIG. 1. Some of the variations in quantities of grain from ears of the same length. Ears 120 and 250 had the same circumference and the same number of rows, but yielded 192 and 137 grams, respectively. Ears 330 and 17 had the same circumference and same number of rows, but yielded 215 and 156 grams of grain, respectively. The differences in weight are due largely to differences in depth of kernel.

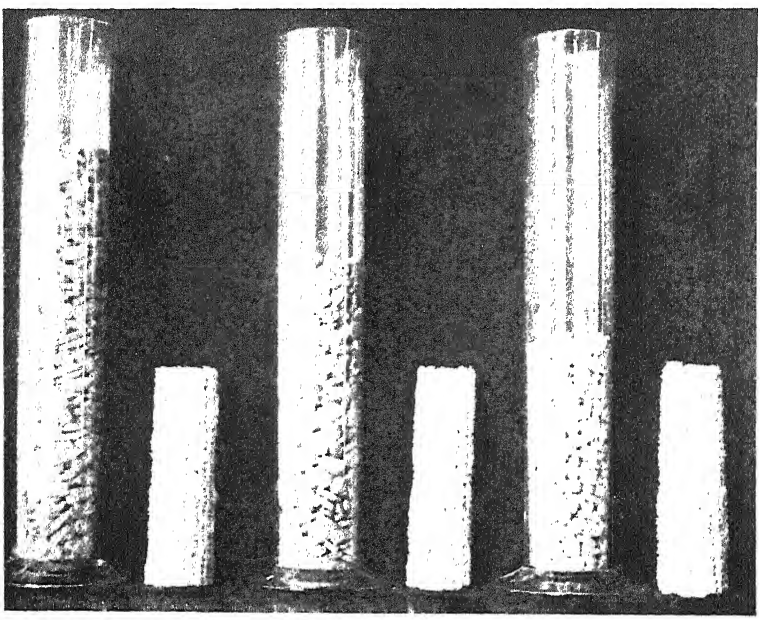

FIG. 2. Some of the extreme variations in quantity of grain from ear sections

to 285 grams, with a mean of 196. It will be seen that there is a positive correlation of .4148 between the circumference of the cob and the weight of grain, with a probable error of $\pm .0095$. As was mentioned above, no ears under 8 inches in length were sectioned and

TABLE I.—*Relation between weight of shelled grain per section in grams, subject; and circumference of cob in centimeters, relative.* $(r = .4118 \pm .00947.)$

Circumference of cob in centimeters.

| Weight of shelled grain in grams. | 7.0 to 7.5 | 7.5 to 8.0 | 8.0 to 8.5 | 8.5 to 9.0 | 9.0 to 9.5 | 9.5 to 10.0 | 10.0 to 10.5 | 10.5 to 11.0 | 11.0 to 11.5 | 11.5 to 12.0 | 12.0 to 12.5 | 12.5 to 13.0 | 13.0 to 13.5 | 13.5 to 14.0 | 14.0 to 14.5 | 14.5 to 15.0 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 105–110 | | | | | | | 2 | | | | | | | | | | 2 |
| 110–115 | | | | | | 1 | | | | | | | | | | | 1 |
| 115–120 | | | | | | | | | | | | | | | | | |
| 120–125 | | | | | 1 | 2 | | | | 1 | | | | | | | 4 |
| 125–130 | | | | 2 | 1 | | | 2 | | | | | | | | | 5 |
| 130–135 | | | | | 1 | | 2 | 3 | | | | | | | | | 6 |
| 135–140 | | | | 2 | 3 | 4 | 2 | 3 | 1 | | | 1 | | | | | 16 |
| 140–145 | 1 | | 1 | | 1 | 1 | 2 | 2 | 3 | 2 | | | | | | | 13 |
| 145–150 | | | | 3 | 6 | 7 | 7 | 6 | | | | 1 | | | | | 30 |
| 150–155 | | | 4 | 2 | 7 | 8 | 8 | 8 | 4 | | 3 | 1 | | | | | 45 |
| 155–160 | | | 4 | 3 | 10 | 20 | 15 | 13 | 7 | 3 | 1 | | | | | | 76 |
| 160–165 | | | 2 | 11 | 16 | 22 | 16 | 9 | 6 | 4 | 3 | 1 | | | | | 90 |
| 165–170 | | 1 | | 9 | 36 | 35 | 29 | 16 | 10 | 8 | 2 | 1 | 1 | | | | 148 |
| 170–175 | | | 2 | 13 | 35 | 48 | 29 | 26 | 13 | 7 | 3 | 1 | | | | | 177 |
| 175–180 | | 1 | 3 | 12 | 30 | 64 | 43 | 38 | 23 | 13 | 2 | 1 | | | | | 230 |
| 180–185 | | | 1 | 7 | 34 | 45 | 52 | 49 | 28 | 17 | 7 | 1 | | | | | 241 |
| 185–190 | | | | 7 | 38 | 53 | 62 | 39 | 40 | 19 | 5 | 1 | | | | | 264 |
| 190–195 | | | 1 | 4 | 36 | 54 | 55 | 68 | 40 | 26 | 6 | 2 | | | | | 292 |
| 195–200 | | | 1 | 8 | 27 | 50 | 77 | 51 | 60 | 18 | 11 | 4 | 3 | | | | 310 |
| 200–205 | | | | 6 | 27 | 55 | 71 | 79 | 44 | 33 | 17 | 3 | 1 | 1 | | | 337 |
| 205–210 | | | | 3 | 14 | 35 | 60 | 58 | 43 | 29 | 12 | 4 | | | | | 258 |
| 210–215 | | | | 1 | 14 | 28 | 48 | 53 | 38 | 23 | 11 | 8 | 1 | | | 1 | 226 |
| 215–220 | | | | 1 | 9 | 14 | 34 | 47 | 48 | 31 | 17 | 2 | 2 | 3 | | | 208 |
| 220–225 | | | | 1 | 4 | 11 | 18 | 28 | 26 | 31 | 18 | 8 | 2 | | 1 | | 148 |
| 225–230 | | | | | 3 | 8 | 15 | 34 | 34 | 31 | 14 | 6 | 2 | | | | 147 |
| 230–235 | | | | | 1 | 4 | 10 | 15 | 17 | 7 | 8 | 5 | 1 | 1 | | | 69 |
| 235–240 | | | | | 1 | 2 | 5 | 11 | 6 | 11 | 8 | 2 | 3 | | | | 49 |
| 240–245 | | | | | | 5 | 3 | 3 | 10 | 7 | 5 | 5 | 1 | | | | 39 |
| 245–250 | | | | | | | 4 | 1 | 3 | 5 | 6 | 4 | 2 | 1 | 1 | | 27 |
| 250–255 | | | | | | | 2 | 1 | 3 | 3 | | 2 | | | | | 11 |
| 255–260 | | | | | | 1 | 1 | 3 | 6 | 1 | 2 | 2 | 1 | 2 | | 1 | 20 |
| 260–265 | | | | | | | | | | 1 | | 2 | 1 | | 1 | | 5 |
| 265–270 | | | | | | | | | | | | 1 | | | | | 1 |
| 270–275 | | | | | | | | 2 | | | | | | | | | 2 |
| 275–280 | | | | | | | | | | | | 2 | | | | | 2 |
| 280–285 | | | | | | | | | | | | 1 | | | | | 1 |
| Totals | 1 | 2 | 19 | 95 | 355 | 577 | 672 | 668 | 513 | 331 | 161 | 72 | 21 | 8 | 3 | 2 | 3,500 |

measured. There was no limit to the circumference of the ears selected. The data indicate that the ears with large cobs carry the most shelled grain. The opinion that large cobs carry shallow kernels resulting in a low yield per ear is not borne out by this study.

## 2. CIRCUMFERENCE OF COB AND WEIGHT OF KERNEL.

In general, cobs of large circumference have a larger number of rows of grain than those of small circumference. The larger the number of rows on an ear, the circumference being the same, the narrower are the kernels. Narrow kernels are likely to be relatively

TABLE 2.—*Correlation between weight of individual kernels (number in 10 grams), subject; and circumference of cob in centimeters, relative.* ($r = -.0185 \pm .01140$.)

Circumference of cob in centimeters.

| Kernels in 10 grams. | 7.0 to 7.5 | 7.5 to 8.0 | 8.0 to 8.5 | 8.6 to 9.0 | 9.0 to 9.5 | 9.5 to 10.0 | 10.0 to 10.5 | 10.5 to 11.0 | 11.0 to 11.5 | 11.5 to 12.0 | 12.0 to 12.5 | 12.5 to 13.0 | 13.0 to 13.5 | 13.5 to 14.0 | 14.0 to 14.5 | 14.5 to 15.0 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | 2 | | | | 1 | | | 1 | | | | 4 |
| 19 | | | | | 3 | 2 | 3 | 2 | | | | 1 | 1 | | | | 12 |
| 20 | | | | | 3 | 8 | 8 | 13 | | 8 | 3 | | | | | | 43 |
| 21 | | | | | 11 | 10 | 15 | 14 | 8 | 6 | 2 | 1 | | | | 1 | 68 |
| 22 | | | | 4 | 6 | 24 | 28 | 45 | 27 | 20 | 4 | 3 | | | | | 161 |
| 23 | | 1 | | 7 | 23 | 30 | 45 | 43 | 42 | 21 | 11 | 3 | 3 | | | | 229 |
| 24 | 1 | | 1 | 6 | 31 | 47 | 48 | 59 | 47 | 29 | 13 | 8 | 6 | | | | 296 |
| 25 | | 1 | 4 | 10 | 30 | 60 | 74 | 58 | 34 | 31 | 13 | 6 | 1 | 3 | | | 325 |
| 26 | | | 2 | 14 | 35 | 68 | 70 | 72 | 49 | 37 | 15 | 6 | 1 | 1 | 1 | | 371 |
| 27 | | | 2 | 8 | 36 | 56 | 75 | 59 | 61 | 34 | 13 | 7 | 2 | 2 | 1 | | 356 |
| 28 | | | 2 | 8 | 30 | 47 | 59 | 45 | 47 | 24 | 13 | 9 | 2 | 1 | 1 | | 288 |
| 29 | | | | 8 | 25 | 34 | 61 | 58 | 41 | 29 | 13 | 6 | | 1 | 1 | | 277 |
| 30 | | | 1 | 4 | 36 | 46 | 38 | 40 | 38 | 12 | 14 | 5 | | | | | 234 |
| 31 | | | 2 | 6 | 22 | 33 | 26 | 38 | 30 | 18 | 7 | 6 | | | | | 188 |
| 32 | | | 2 | 5 | 21 | 27 | 31 | 37 | 25 | 20 | 8 | 1 | 2 | | | | 179 |
| 33 | | | | 2 | 10 | 20 | 22 | 21 | 15 | 17 | 11 | | | | | | 118 |
| 34 | | | 2 | 7 | 9 | 16 | 19 | 14 | 12 | 6 | 8 | 2 | | | | | 95 |
| 35 | | | | | 4 | 12 | 10 | 10 | 9 | 7 | 4 | 2 | 1 | | | | 59 |
| 36 | | | | 2 | 9 | 7 | 10 | 9 | 10 | 1 | 4 | 2 | | | | | 54 |
| 37 | | | 1 | 1 | 5 | 7 | 5 | 7 | 2 | 6 | 2 | 1 | | | | | 37 |
| 38 | | | | 1 | 2 | 8 | 5 | 4 | 6 | 2 | | 1 | | | | | 29 |
| 39 | | | | | | 5 | 4 | 11 | 2 | 1 | 3 | | 1 | | | | 27 |
| 40 | | | | 1 | | 2 | 4 | 2 | 1 | 1 | | | | | | | 11 |
| 41 | | | | 1 | 2 | 1 | 6 | 2 | 3 | | | 1 | | | | | 16 |
| 42 | | | | | 1 | 3 | 4 | 1 | 1 | | | | | | | | 10 |
| 43 | | | | | | 2 | | 2 | 1 | | | 1 | | | | | 6 |
| 44 | | | | | 1 | | | 1 | | | | | | | | | 2 |
| 45 | | | | | | | | | 1 | | | | | | | | 1 |
| 46 | | | | | | | 1 | | | | | | | | | | 1 |
| 47 | | | | | | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | | | | | | |
| 49 | | | | | | | | 1 | | | | | | | | | 1 |
| 50 | | | | | | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | | | | | |
| 52 | | | | | | | 1 | | 1 | | | | | | | | 2 |
| Totals | 1 | 2 | 19 | 95 | 355 | 577 | 672 | 668 | 513 | 331 | 161 | 72 | 21 | 8 | 4 | 1 | 3,500 |

lighter in weight than broad kernels. On the other hand, an ear with a small number of rows is likely to have rather wide kernels. Table 2 shows that the correlation between the circumference of the

cob and the weight of the kernel is $-.0185 \pm .0114$, which is practically negligible in value. In this variety of corn the weight of the kernel does not seem related to the circumference of the cob. The undersized kernels which are often seen on ears of small diameter are probably offset in weight by the longer kernels which are common in ears of large diameter. The density of cobs and kernels respectively is also a factor that affects the relation. It is interesting to note that the coefficient of variability is high for both characters, being 19.97 for the circumference of the cobs and 16.18 for the weight of the kernel.

### 3. CIRCUMFERENCE OF COB AND DEPTH OF KERNEL.

It is commonly supposed that ears with cobs of large circumference have shallow kernels. Table 3 shows that the coefficient of correlation between the circumference of cob and the depth of kernel is $-.1789 \pm .0710$, indicating that there is a moderate tendency for large cobs to carry shallow kernels. The extremes of depth of kernel range from 0.7 to 1.9 cm. with a mean of 1.2 cm. The coefficient of variability in kernels is 10.78, much less than that for circumference of cob.

TABLE 3.—*Correlation between depth of kernel in centimeters, subject; and circumference of cob in centimeters, relative.* ($r = -.1789 \pm .01104$.)

| Depth of kernels, centimeters | Circumference of cob in centimeters. 7.0 to 7.5 | 7.5 to 8.0 | 8.0 to 8.5 | 8.5 to 9.0 | 9.0 to 9.5 | 9.5 to 10.0 | 10.0 to 10.5 | 10.5 to 11.0 | 11.0 to 11.5 | 11.5 to 12.0 | 12.0 to 12.5 | 12.5 to 13.0 | 13.0 to 13.5 | 13.5 to 14.0 | 14.0 to 14.5 | 14.5 to 15.0 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .7– .8 | | | | | | | 1 | | | | | | | | | | 1 |
| .8– .9 | | | | | | 1 | 2 | 4 | 1 | 2 | 2 | 3 | | | | | 15 |
| .9–1.0 | | | | 1 | 3 | 4 | 6 | 17 | 9 | 14 | 8 | 2 | 1 | | | | 65 |
| 1.0–1.1 | | | 2 | 6 | 23 | 44 | 61 | 64 | 62 | 45 | 27 | 17 | 3 | 2 | 2 | | 358 |
| 1.1–1.2 | 1 | | 2 | 23 | 63 | 133 | 161 | 162 | 153 | 95 | 49 | 17 | 9 | 3 | | | 871 |
| 1.2–1.3 | | 1 | 7 | 25 | 104 | 172 | 187 | 191 | 133 | 92 | 41 | 14 | 5 | 1 | 2 | 1 | 976 |
| 1.3–1.4 | | 1 | 4 | 25 | 97 | 129 | 151 | 159 | 99 | 51 | 26 | 11 | 2 | | | | 755 |
| 1.4–1.5 | | | 3 | 13 | 54 | 71 | 81 | 54 | 44 | 28 | 7 | 7 | 1 | 2 | | | 365 |
| 1.5–1.6 | | | 1 | | 10 | 19 | 18 | 16 | 10 | 4 | 1 | | | | | | 79 |
| 1.6–1.7 | | | | 2 | 1 | 4 | 3 | 1 | 1 | | | 1 | | | | | 13 |
| 1.7–1.8 | | | | | | | 1 | | 1 | | | | | | | | 2 |
| Totals | 1 | 2 | 19 | 95 | 355 | 577 | 672 | 668 | 513 | 331 | 161 | 72 | 21 | 8 | 4 | 1 | 3,500 |

### 4. CIRCUMFERENCE OF COB AND THICKNESS OF KERNEL.

An examination of Table 4 shows that there is a slight negative correlation between the circumference of the cob and the thickness

of kernel. The correlation factor is —.1053 ± .0113. This indicates that the smaller cobs are more likely to have thick kernels. The extremes of thickness of kernel range from 18 to 32 kernels to cover 19 cm., with a coefficient of variability of 8.11. The coefficient of variability is less for thickness of kernel than for any other character studied.

TABLE 4.—*Correlation between thickness of kernel (number in 10 centimeters), subject; and circumference of cob in centimeters, relative.*
($r$ = —.1053 ± .01127.)

| Number of kernels in 10 centimeters. | Circumference of cob in centimeters. 7.0–7.5 | 7.5–8.0 | 8.0–8.5 | 8.5–9.0 | 9.0–9.5 | 9.5–10.0 | 10.0–10.5 | 10.5–11.0 | 11.0–11.5 | 11.5–12.0 | 12.0–12.5 | 12.5–13.0 | 13.0–13.5 | 13.5–14.0 | 14.0–14.5 | 14.5–15.0 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | 1 | 1 | | 1 | | | | | | | | 3 |
| 19 | | | | | | 3 | | 1 | 2 | 1 | | | | | | | 7 |
| 20 | | | | 1 | 1 | 4 | 6 | 5 | 7 | 3 | 3 | 2 | 2 | | 1 | | 35 |
| 21 | | | | 3 | 9 | 17 | 18 | 12 | 11 | 13 | 6 | 3 | 5 | 1 | | | 98 |
| 22 | | 1 | 3 | 2 | 25 | 30 | 48 | 69 | 34 | 35 | 14 | 3 | 1 | | | | 265 |
| 23 | 1 | | | 9 | 37 | 78 | 89 | 88 | 72 | 61 | 21 | 13 | 2 | 1 | 1 | 1 | 474 |
| 24 | | | 1 | 19 | 75 | 106 | 122 | 133 | 104 | 72 | 38 | 15 | 3 | 2 | 1 | | 691 |
| 25 | | | 6 | 22 | 74 | 115 | 133 | 126 | 98 | 56 | 28 | 13 | 3 | 4 | | | 678 |
| 26 | | | 6 | 16 | 47 | 97 | 110 | 117 | 83 | 47 | 28 | 14 | 3 | | | | 568 |
| 27 | | 1 | 2 | 11 | 44 | 58 | 82 | 69 | 47 | 19 | 12 | 4 | | | 1 | | 350 |
| 28 | | | 1 | 7 | 22 | 36 | 34 | 30 | 35 | 18 | 6 | 5 | 1 | | | | 195 |
| 29 | | | | 3 | 13 | 21 | 13 | 15 | 13 | 4 | 4 | | | | | | 86 |
| 30 | | | | 1 | 4 | 8 | 13 | 3 | 6 | 2 | 1 | | 1 | | | | 39 |
| 31 | | | | 1 | 3 | 3 | 3 | | | | | | | | | | 10 |
| 32 | | | | | 1 | | | | | | | | | | | | 1 |
| Totals | 1 | 2 | 19 | 95 | 355 | 577 | 672 | 668 | 513 | 331 | 161 | 72 | 21 | 8 | 4 | 1 | 3,500 |

### 5. WEIGHT OF COB AND WEIGHT OF GRAIN.

Table 5 shows the relation between the weight of cob and the weight of grain. The extremes for weight of cob range from 15 to 75 grams; for weight of grain, 105 to 285 grams. The correlation factor is .3064 ± .0103, indicating a fairly close relationship between these two characters. A comparison with Table 1 shows a stronger correlation between the circumference of cob and weight of grain than between the latter and weight of cob. This indicates that the weight of cob is a more variable factor than the circumference. The coefficient of variability for circumference is 9.24 ± .075, and for weight of cob, 19.97 ± .168.

### 6. WEIGHT OF COB AND WEIGHT OF KERNEL.

The weight of kernel as expressed by the number required to weigh 10 grams ranges from 18 to 32. The coefficient of variability is

16.18 $\pm$ .1344. The factor of correlation between these two characters is $-$.1837 $\pm$ .0110. This shows there is no correlation between high percentage of cob and high weight of kernel. It predicts a moderate tendency for heavy cobs to produce light kernels. In Table

TABLE 5.—*Relation between weight of shelled grain per section in grams, subject; and weight of cob per section in grams.* ($r = .3064 \pm .0103$.)

Weight of cob in grams.

| Weight of shelled corn in grams. | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 105–110 | | 1 | | 1 | | | | | | | | | 2 |
| 110–115 | 1 | | | | | | | | | | | | 1 |
| 115–120 | | | | | | | | | | | | | |
| 120–125 | 1 | 1 | 1 | | 1 | | | | | | | | 4 |
| 125–130 | 1 | 2 | | 2 | | | | | | | | | 5 |
| 130–135 | | 1 | 2 | | 2 | | 1 | | | | | | 6 |
| 135–140 | 1 | 1 | 4 | 6 | 4 | | | | | | | | 16 |
| 140–145 | | 3 | 2 | 3 | 4 | 1 | | | | | | | 13 |
| 145–150 | | 4 | 7 | 5 | 6 | 6 | 1 | 1 | | | | | 30 |
| 150–155 | 1 | 4 | 12 | 11 | 11 | 5 | | 1 | | | | | 45 |
| 155–160 | | 4 | 20 | 27 | 14 | 10 | 1 | | | | | | 76 |
| 160–165 | | 11 | 21 | 20 | 23 | 10 | 5 | | | | | | 90 |
| 165–170 | 1 | 12 | 29 | 54 | 33 | 15 | 4 | | | | | | 148 |
| 170–175 | 1 | 14 | 34 | 59 | 35 | 21 | 7 | 6 | | | | | 177 |
| 175–180 | | 15 | 39 | 82 | 52 | 28 | 10 | 2 | 2 | | | | 230 |
| 180–185 | 1 | 11 | 42 | 66 | 61 | 44 | 13 | 3 | | | | | 241 |
| 185–190 | | 6 | 38 | 80 | 75 | 47 | 15 | 3 | | | | | 264 |
| 190–195 | | 7 | 41 | 93 | 70 | 55 | 24 | | | | | | 292 |
| 195–200 | | 8 | 50 | 77 | 91 | 59 | 21 | 3 | 1 | | | | 310 |
| 200–205 | | 8 | 36 | 93 | 90 | 61 | 39 | 6 | 4 | | | | 337 |
| 205–210 | 2 | 5 | 30 | 53 | 80 | 44 | 31 | 10 | 2 | 1 | | | 258 |
| 210–215 | | 5 | 21 | 60 | 63 | 50 | 16 | 7 | 3 | 1 | | | 226 |
| 215–220 | | | 21 | 39 | 61 | 43 | 25 | 12 | 4 | 2 | 1 | | 208 |
| 220–225 | | 2 | 18 | 37 | 40 | 27 | 10 | 9 | 5 | | | | 148 |
| 225–230 | | | 12 | 22 | 38 | 43 | 14 | 14 | 1 | 3 | | | 147 |
| 230–235 | | | 3 | 16 | 19 | 20 | 7 | 4 | | | | | 69 |
| 235–240 | | 1 | 3 | 7 | 13 | 7 | 13 | 3 | | 1 | | 1 | 49 |
| 240–245 | | | 3 | 9 | 7 | 11 | 7 | 1 | | 1 | | | 39 |
| 245–250 | | | 1 | 4 | 7 | 6 | 4 | 4 | 1 | | | | 27 |
| 250–255 | | | 1 | 5 | 3 | | 2 | | | | | | 11 |
| 255–260 | | | | 3 | 6 | 4 | 1 | | 4 | 2 | | | 20 |
| 260–265 | | | | | | 2 | 1 | 2 | | | | | 5 |
| 265–270 | | | | | | 1 | | | | | | | 1 |
| 270–275 | | | | | | | 1 | 1 | | | | | 2 |
| 275–280 | | | | | | | 1 | 1 | | | | | 2 |
| 280–285 | | | | | | | | 1 | | | | | 1 |
| Totals | 10 | 126 | 491 | 934 | 909 | 620 | 274 | 94 | 29 | 11 | 1 | 1 | 3,500 |

2 it was found that there was no correlation between the circumference of the cob and the weight of kernel. This would lead to the conclusion that no very high correlation exists between the circumference of cob and the weight of cob. Large cobs may lack normal density and for that reason are not proportionally heavier than small cobs.

TABLE 6.—*Correlation between weight of individual kernel (number in 10 grams), subject; and weight of cob in grams, relative.* ($r = -.1837 \pm .011.$)

| Number of kernels in 10 grams. | Weight of cob in grams. 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | 1 | 1 | 2 | | | | | | 4 |
| 19 | | | 4 | 1 | 3 | 1 | | 3 | | | | | 12 |
| 20 | | 1 | 3 | 5 | 16 | 9 | 7 | 1 | 1 | | | | 43 |
| 21 | | 2 | 10 | 10 | 22 | 14 | 6 | 3 | 1 | | | | 68 |
| 22 | | 3 | 10 | 31 | 42 | 40 | 25 | 6 | 4 | | | | 161 |
| 23 | 1 | 7 | 24 | 58 | 48 | 56 | 19 | 13 | 2 | 1 | | | 229 |
| 24 | | 10 | 26 | 79 | 77 | 56 | 27 | 7 | 11 | 2 | | 1 | 296 |
| 25 | 1 | 11 | 31 | 70 | 100 | 68 | 30 | 9 | 1 | 4 | | | 325 |
| 26 | 1 | 6 | 47 | 118 | 88 | 71 | 27 | 11 | 2 | | | | 371 |
| 27 | | 11 | 43 | 92 | 101 | 74 | 22 | 7 | 4 | 1 | 1 | | 356 |
| 28 | 1 | 9 | 47 | 72 | 80 | 41 | 23 | 13 | 1 | 1 | | | 288 |
| 29 | 1 | 11 | 35 | 89 | 71 | 38 | 23 | 9 | | | | | 277 |
| 30 | | 16 | 39 | 78 | 44 | 35 | 19 | 3 | | | | | 234 |
| 31 | | 5 | 36 | 52 | 52 | 25 | 13 | 4 | 1 | | | | 188 |
| 32 | | 10 | 30 | 59 | 43 | 22 | 11 | 1 | 1 | 2 | | | 179 |
| 33 | | 4 | 30 | 24 | 28 | 24 | 7 | 1 | | | | | 118 |
| 34 | 2 | 6 | 20 | 24 | 21 | 16 | 3 | 3 | | | | | 95 |
| 35 | | 2 | 14 | 13 | 19 | 7 | 4 | | | | | | 59 |
| 36 | | 5 | 8 | 15 | 17 | 8 | 1 | | | | | | 54 |
| 37 | | 1 | 10 | 11 | 11 | 4 | | | | | | | 37 |
| 38 | | 3 | 10 | 9 | 3 | 3 | 1 | | | | | | 29 |
| 39 | | 1 | 2 | 6 | 11 | 4 | 3 | | | | | | 27 |
| 40 | | 1 | 3 | 5 | | 1 | 1 | | | | | | 11 |
| 41 | 1 | 1 | 3 | 4 | 5 | 2 | | | | | | | 16 |
| 42 | 1 | | 5 | 1 | 3 | | | | | | | | 10 |
| 43 | 1 | | 1 | 2 | 2 | | | | | | | | 6 |
| 44 | | | | 2 | | | | | | | | | 2 |
| 45 | | | | 1 | | | | | | | | | 1 |
| 46 | | | | 1 | | | | | | | | | 1 |
| 47 | | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | | |
| 49 | | | | 1 | | | | | | | | | 1 |
| 50 | | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | |
| 52 | | | | 1 | 1 | | | | | | | | 2 |
| Totals | 10 | 126 | 491 | 934 | 909 | 620 | 274 | 94 | 29 | 11 | 1 | 1 | 3,500 |

### 7. WEIGHT OF COB AND DEPTH OF KERNEL.

Table 7 shows that correlation between the weight of cob and the depth of kernel is —.0747, with a probable error of ± .0113. The correlation is negative and very low. Large cobs by weight are not accompanied by deep kernels. Large cobs by volume, as shown in Table 3, tend to carry shallow kernels.

### 8. WEIGHT OF COB AND THICKNESS OF KERNEL.

An examination of Table 8 shows a correlation of —.15 between the weight of cob and the thickness of kernel, with a probable error of ± .0111. There is moderate indication that heavy cobs tend to

TABLE 7.—*Correlation between depth of kernel in centimeters, subject; and weight of cob in grams, relative.* ($r = -.0747 \pm .0113$.)

| Depth of kernels in centimeters. | Weight of cob in grams. 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .7– .8 | | 1 | | | | | | | | | | | 1 |
| .8– .9 | 1 | | 5 | 1 | 3 | 2 | 2 | 1 | | | | | 15 |
| .9–1.0 | 2 | 3 | 5 | 11 | 22 | 15 | 7 | | | | | | 65 |
| 1.0–1.1 | 1 | 9 | 38 | 99 | 78 | 70 | 50 | 12 | 1 | | | | 358 |
| 1.1–1.2 | 1 | 28 | 124 | 228 | 206 | 166 | 82 | 22 | 8 | 4 | 1 | 1 | 871 |
| 1.2–1.3 | 3 | 42 | 114 | 236 | 280 | 193 | 73 | 23 | 11 | 1 | | | 976 |
| 1.3–1.4 | 1 | 29 | 123 | 229 | 182 | 117 | 42 | 25 | 5 | 2 | | | 755 |
| 1.4–1.5 | 1 | 11 | 66 | 102 | 108 | 48 | 14 | 8 | 3 | 4 | | | 365 |
| 1.5–1.6 | | 3 | 12 | 24 | 26 | 8 | 3 | 2 | 1 | | | | 79 |
| 1.6–1.7 | | | 3 | 4 | 3 | 1 | 1 | 1 | | | | | 13 |
| 1.7–1.8 | | | 1 | | 1 | | | | | | | | 2 |
| Totals | 10 | 126 | 491 | 934 | 909 | 620 | 274 | 94 | 29 | 11 | 1 | 1 | 3,500 |

carry thin kernels rather than thick. In Table 4 it was shown that large cobs by volume were more likely to be accompanied by thin kernels. Small cobs both by volume and weight seem to be associated with thick kernels.

TABLE 8.—*Correlation between thickness of kernel (number in 10 centimeters), subject; and weight of cob in grams, relative.* ($r = -.1500 \pm .0111$.)

| Number of kernels in 10 centimetres. | Weight of cob in grams. 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | 1 | | 2 | | | | | | | | | 3 |
| 19 | | | 2 | 1 | 2 | 1 | 1 | | | | | | 7 |
| 20 | | 1 | 4 | 5 | 8 | 6 | 7 | 2 | 2 | | | | 35 |
| 21 | | 4 | 10 | 28 | 20 | 18 | 12 | 4 | 2 | | | | 98 |
| 22 | 1 | 8 | 26 | 69 | 63 | 62 | 23 | 8 | 4 | 1 | | | 265 |
| 23 | | 9 | 47 | 121 | 120 | 98 | 49 | 23 | 5 | 1 | | 1 | 474 |
| 24 | 3 | 21 | 89 | 176 | 167 | 142 | 66 | 14 | 8 | 5 | | | 691 |
| 25 | 1 | 26 | 93 | 197 | 188 | 105 | 43 | 14 | 7 | 3 | 1 | | 678 |
| 26 | 1 | 16 | 81 | 157 | 163 | 88 | 46 | 16 | | | | | 568 |
| 27 | 1 | 21 | 73 | 90 | 85 | 58 | 14 | 7 | 1 | | | | 350 |
| 28 | 2 | 9 | 33 | 53 | 54 | 28 | 9 | 6 | | 1 | | | 195 |
| 29 | 1 | 8 | 15 | 22 | 29 | 7 | 4 | | | | | | 86 |
| 30 | | 2 | 10 | 10 | 10 | 7 | | | | | | | 39 |
| 31 | | | 7 | 3 | | | | | | | | | 10 |
| 32 | | | 1 | | | | | | | | | | 1 |
| Totals | 10 | 126 | 491 | 934 | 909 | 620 | 274 | 94 | 29 | 11 | 1 | 1 | 3,500 |

### 9. DENSITY OF COB AND WEIGHT OF GRAIN PER SECTION.

It will be noted from Table 13 that the coefficient of variability of the density of cob is quite high, $17.51 \pm .1460$. The extremes of

density of cob range from 0.12 to 0.54 (factor). The examination of a large number of ears will show a wide variation in the density as well as the size (circumference) of cobs. What relation density of cob holds to the yield of grain is shown in Table 9. The coefficient

TABLE 9.—*Correlation between weight of shelled grain per section in grams, subject; and density of cob, relative.* ($r = -.0728 \pm .0113$.)

| Weight of kernels in grams. | Density of cob (factor). | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .12–.14 | .14–.16 | .16–.18 | .18–.20 | .20–.22 | .22–.24 | .24–.26 | .26–.28 | .28–.30 | .30–.32 | .32–.34 | .34–.36 | .36–.38 | .38–.40 | .40–.42 | .42–.44 | .44–.46 | .46–.48 | .48–.50 | .50–.52 | .52–.54 | Totals |
| 105–110 | | | | | 1 | | | | | 1 | | | | | | | | | | | | 2 |
| 110–115 | | | | 1 | | | | | | | | | | | | | | | | | | 1 |
| 115–120 | | | | | | | | | | | | | | | | | | | | | | |
| 120–125 | | | | | | 2 | | 2 | | | | | | | | | | | | | | 4 |
| 125–130 | | | | | | | 1 | 1 | | 3 | | | | | | | | | | | | 5 |
| 130–135 | | | | | | 1 | 1 | | 1 | 1 | | | 1 | | | 1 | | | | | | 6 |
| 135–140 | | | 1 | | 1 | 1 | | 2 | 3 | 1 | 1 | 5 | | 1 | | | | | | | | 16 |
| 140–145 | | | | | | 1 | 1 | 1 | 4 | 2 | 3 | | | 1 | | | | | | | | 13 |
| 145–150 | | | | | | 3 | | 2 | 1 | 8 | 3 | 4 | | 4 | 5 | | | | | | | 30 |
| 150–155 | | | | 3 | 3 | 1 | 1 | 3 | 6 | 5 | 7 | 4 | 5 | 2 | | 1 | 2 | 1 | | | 1 | 45 |
| 155–160 | | | | | | 3 | 4 | 9 | 8 | 12 | 11 | 11 | 10 | 2 | 2 | 4 | | | | | | 76 |
| 160–165 | | | | | 1 | 4 | 5 | 8 | 11 | 11 | 14 | 9 | 9 | 1 | 4 | 5 | 5 | | 2 | 1 | | 90 |
| 165–170 | | | | | 2 | 4 | 10 | 12 | 17 | 21 | 21 | 10 | 19 | 13 | 4 | 7 | 4 | 3 | 1 | | | 148 |
| 170–175 | | | | | 1 | 3 | 7 | 22 | 17 | 19 | 26 | 18 | 21 | 18 | 11 | 8 | 3 | 1 | 1 | | 1 | 177 |
| 175–180 | | | | | 6 | 5 | 13 | 24 | 27 | 26 | 26 | 30 | 14 | 24 | 15 | 9 | 3 | 5 | | 2 | | 230 |
| 180–185 | | | | | 4 | 8 | 9 | 26 | 24 | 36 | 24 | 38 | 26 | 17 | 12 | 11 | 5 | | | 1 | | 241 |
| 185–190 | | | | | 1 | 4 | 23 | 18 | 27 | 31 | 34 | 36 | 33 | 18 | 12 | 13 | 9 | 3 | 2 | | | 264 |
| 190–195 | | | | 1 | 3 | 7 | 14 | 31 | 34 | 36 | 38 | 38 | 20 | 41 | 13 | 11 | 1 | 2 | 2 | | | 292 |
| 195–200 | | | | | 4 | 10 | 20 | 32 | 40 | 38 | 48 | 32 | 34 | 21 | 13 | 10 | 3 | 5 | | | | 310 |
| 200–205 | | | 2 | | 6 | 7 | 21 | 20 | 46 | 44 | 53 | 41 | 38 | 27 | 10 | 10 | 5 | 4 | | 3 | | 337 |
| 205–210 | 1 | | | 1 | 1 | 6 | 19 | 24 | 27 | 34 | 27 | 37 | 24 | 29 | 14 | 8 | 1 | 3 | | 1 | 1 | 258 |
| 210–215 | | | | 2 | 3 | 7 | 13 | 19 | 36 | 34 | 26 | 31 | 22 | 15 | 6 | 6 | 3 | 3 | | | | 226 |
| 215–220 | | | | | 5 | 10 | 17 | 16 | 24 | 19 | 34 | 29 | 22 | 10 | 7 | 8 | 1 | 3 | 2 | | 1 | 208 |
| 220–225 | | | | 1 | 6 | 8 | 18 | 26 | 21 | 19 | 14 | 9 | 12 | 4 | 4 | 3 | 2 | | | 1 | | 148 |
| 225–230 | | | | 3 | 1 | 4 | 8 | 13 | 14 | 32 | 25 | 15 | 12 | 8 | 5 | 4 | 3 | | | | | 147 |
| 230–235 | | | | | 2 | | 4 | 13 | 7 | 15 | 9 | 6 | 7 | 4 | 1 | 1 | | | | | | 69 |
| 235–240 | | | | | 2 | | 7 | 7 | 4 | 8 | 5 | 5 | 5 | 3 | 2 | 1 | | | | | | 49 |
| 240–245 | | | | | | 5 | 2 | 5 | 8 | 6 | 4 | 5 | 1 | 1 | 1 | 1 | | | | | | 39 |
| 245–250 | | | | | | 3 | 3 | 5 | 8 | 1 | 3 | 2 | 1 | 1 | | | | | | | | 27 |
| 250–255 | | | | | | 1 | 3 | 1 | 3 | 1 | 1 | 1 | | | | | | | | | | 11 |
| 255–260 | | | | | | 1 | 1 | 1 | 2 | 5 | 4 | 2 | 2 | 1 | | 1 | | | | | | 20 |
| 260–265 | | | | | | | 2 | | | 2 | 1 | | | | | | | | | | | 5 |
| 265–270 | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| 270–275 | | | | | | | | | | | | | | | 1 | | 1 | | | | | 2 |
| 275–280 | | | | | | | | | | 2 | | | | | | | | | | | | 2 |
| 280–285 | | | | | | | | | | | 1 | | | | | | | | | | | 1 |
| Totals | 1 | 0 | 3 | 12 | 53 | 109 | 228 | 343 | 420 | 473 | 463 | 418 | 338 | 266 | 143 | 123 | 51 | 33 | 10 | 9 | 4 | 3,500 |

of correlation is low and negative, $-.0728 \pm .0113$. This indicates a very slight tendency for high-yielding ears to be associated with cobs of low density.

### 10. DENSITY OF COB AND WEIGHT OF KERNEL.

An inspection of Table 10 shows a moderate negative correlation between the density of cob and the weight of kernel. The coefficient of correlation factor is $-.1759 \pm .0111$. The relation between the two characters is to the effect that lighter kernels accompany the cobs of the greater density. It has been found in carrying on this work

TABLE 10.—*Correlation between weight of individual kernel (number in 10 grams) subject; and density of cob, relative.* ($r = -.1759 \pm .01105$.)

Density of cob (factor).

| Number of kernels in 10 grams. | .12–.14 | .14–.16 | .16–.18 | .18–.20 | .20–.22 | .22–.24 | .24–.26 | .26–.28 | .28–.30 | .30–.32 | .32–.34 | .34–.36 | .36–.38 | .38–.40 | .40–.42 | .42–.44 | .44–.46 | .46–.48 | .48–.50 | .50–.52 | .52–.54 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | 1 | | | | | | 1 | | 1 | | | | 1 | | | | 4 |
| 19 | | | | | | | | | 2 | 4 | 2 | | 1 | 2 | | | | | | | 1 | 12 |
| 20 | | | | | | | | 3 | 1 | 9 | 8 | 9 | 2 | 4 | 3 | 2 | 1 | | | 1 | | 43 |
| 21 | | | | | 1 | 2 | 3 | 5 | 4 | 10 | 11 | 5 | 10 | 10 | 3 | | 3 | | | 1 | | 68 |
| 22 | | | | 1 | 2 | | 8 | 8 | 17 | 18 | 23 | 23 | 21 | 19 | 6 | 7 | 2 | 4 | | 1 | 1 | 161 |
| 23 | | | | 1 | | 7 | 9 | 20 | 27 | 26 | 29 | 33 | 34 | 17 | 7 | 10 | 4 | 3 | 1 | 1 | | 229 |
| 24 | | | | 1 | 4 | 3 | 22 | 20 | 39 | 31 | 41 | 29 | 38 | 27 | 16 | 10 | 6 | 6 | 1 | 2 | | 296 |
| 25 | | | 1 | | 3 | 9 | 14 | 16 | 28 | 33 | 62 | 44 | 33 | 24 | 22 | 21 | 7 | 5 | 2 | | 1 | 325 |
| 26 | | | | | 9 | 5 | 18 | 43 | 46 | 45 | 41 | 60 | 41 | 24 | 17 | 11 | 7 | 2 | | 1 | 1 | 371 |
| 27 | | | | 1 | 3 | 11 | 32 | 25 | 45 | 42 | 52 | 42 | 30 | 31 | 19 | 14 | 4 | 3 | | 2 | | 356 |
| 28 | | | | 2 | 3 | 7 | 25 | 30 | 33 | 34 | 42 | 43 | 22 | 22 | 9 | 8 | 6 | 1 | 1 | | | 288 |
| 29 | 1 | | | | 6 | 11 | 22 | 27 | 37 | 51 | 26 | 23 | 28 | 26 | 9 | 8 | 1 | | 1 | | | 277 |
| 30 | | | 1 | 3 | 2 | 9 | 18 | 32 | 19 | 39 | 30 | 21 | 21 | 15 | 6 | 13 | 2 | 1 | 2 | | | 234 |
| 31 | | | | 1 | 1 | 7 | 7 | 22 | 37 | 30 | 20 | 22 | 15 | 12 | 6 | 4 | 2 | 1 | 1 | | | 188 |
| 32 | | | | | 3 | 7 | 14 | 22 | 28 | 28 | 24 | 20 | 11 | 4 | 7 | 6 | 1 | 4 | | | | 179 |
| 33 | | | | | 4 | 5 | 12 | 17 | 18 | 18 | 13 | 7 | 11 | 4 | 5 | 2 | 2 | | | | | 118 |
| 34 | | | 1 | | 5 | 4 | 5 | 11 | 7 | 13 | 13 | 15 | 6 | 6 | 5 | 1 | 2 | | 1 | | | 95 |
| 35 | | | | | 2 | 3 | 7 | 14 | 4 | 12 | 3 | 4 | 3 | 3 | 2 | 2 | 1 | | | | | 59 |
| 36 | | | | | 1 | 4 | | 8 | 11 | 10 | 5 | 7 | 1 | 5 | | 2 | | | | | | 54 |
| 37 | | | | 1 | 1 | 4 | 2 | 5 | 5 | 6 | 3 | 2 | 4 | 1 | 1 | | | 2 | | | | 37 |
| 38 | | | | | | 2 | 6 | 6 | 1 | 4 | 6 | 2 | | 2 | | | | | | | | 29 |
| 39 | | | | | 2 | 1 | 2 | 3 | 3 | 4 | 2 | 1 | 3 | 6 | | | | | | | | 27 |
| 40 | | | | | | 3 | | 1 | 1 | | 2 | 2 | | | | 2 | | | | | | 11 |
| 41 | | | | | | 2 | 1 | 1 | 4 | 2 | 3 | 1 | 1 | 1 | | | | | | | | 16 |
| 42 | | | | | | 1 | | 2 | 2 | 1 | 1 | 1 | 2 | | | | | | | | | 10 |
| 43 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 | | | | | | | | | | | 6 |
| 44 | | | | | | | | 1 | | | | 1 | | | | | | | | | | 2 |
| 45 | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| 46 | | | | | | | | | 1 | | | | | | | | | | | | | 1 |
| 47 | | | | | | | | | | | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | | | | | | | | | | | |
| 49 | | | | | | | | | | 1 | | | | | | | | | | | | 1 |
| 50 | | | | | | | | | | | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | | | | | | | | | | |
| 52 | | | | | | | | | | 2 | | | | | | | | | | | | 2 |
| Totals | 1 | 0 | 3 | 12 | 53 | 109 | 228 | 343 | 420 | 473 | 463 | 418 | 338 | 266 | 143 | 123 | 51 | 33 | 10 | 9 | 4 | 3,500 |

that the cobs of the greatest density are not the largest in circumference. The cobs of smallest circumference have a tendency to carry a smaller number of rows of kernels and these in turn are generally more shallow than on cobs of larger circumference.

### 11. DENSITY OF COB AND THE DEPTH OF KERNEL.

From the conclusion reached in the discussion of Table 10 we should expect some correlation between the density of cob and depth of kernel. Large volume in cobs is not accompanied by the greatest density. Cobs of large circumference do not carry the largest kernels by weight. The coefficient of correlation between the density of cob and the depth of kernel is .1039 ± .0113. The correlation is positive in a rather low degree, and indicates that depth of kernel is associated to some extent with density of cob.

TABLE 11.—*Correlation between density of cob, subject; and depth of kernel in centimeters, relative.* ($r = .1039 \pm .0113$.)

| Density of cob (factor). | Depth of kernels in centimeters. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .7–.8 | .8–.9 | .9–1.0 | 1.0–1.1 | 1.1–1.2 | 1.2–1.3 | 1.3–1.4 | 1.4–1.5 | 1.5–1.6 | 1.6–1.7 | 1.7–1.8 | Totals |
| .12–14 | | | | | | 1 | | | | | | 1 |
| .14–16 | | | | | | | | | | | | |
| .16–18 | | | 1 | | 1 | 1 | | | | | | 3 |
| .18–20 | | 2 | 2 | 1 | 2 | 2 | 2 | 1 | | | | 12 |
| .20–22 | 1 | 1 | 2 | 8 | 14 | 13 | 9 | 4 | | 1 | | 53 |
| .22–24 | | 3 | 3 | 12 | 33 | 24 | 21 | 10 | 3 | | | 109 |
| .24–26 | | 3 | 5 | 29 | 52 | 58 | 51 | 23 | 5 | 1 | 1 | 228 |
| .26–28 | | 1 | 8 | 38 | 93 | 88 | 78 | 34 | 3 | | | 343 |
| .28–30 | | 1 | 12 | 50 | 117 | 114 | 90 | 28 | 7 | | 1 | 420 |
| .30–32 | | 1 | 13 | 51 | 121 | 122 | 90 | 55 | 18 | 2 | | 473 |
| .32–34 | | 1 | 8 | 42 | 119 | 125 | 104 | 51 | 11 | 2 | | 463 |
| .34–36 | | 1 | 7 | 41 | 97 | 135 | 78 | 48 | 9 | 2 | | 418 |
| .36–38 | | | 1 | 37 | 85 | 83 | 89 | 38 | 5 | | | 338 |
| .38–40 | | | 2 | 20 | 56 | 87 | 63 | 30 | 6 | 2 | | 266 |
| .40–42 | | 1 | 1 | 12 | 35 | 51 | 30 | 8 | 4 | 1 | | 143 |
| .42–44 | | | | 12 | 25 | 36 | 22 | 21 | 5 | 2 | | 123 |
| .44–46 | | | | 3 | 10 | 19 | 10 | 8 | 1 | | | 51 |
| .46–48 | | | | 1 | 7 | 11 | 9 | 4 | 1 | | | 33 |
| .48–50 | | | | | 2 | 4 | 2 | 1 | 1 | | | 10 |
| .50–52 | | | | | 2 | 2 | 4 | 1 | | | | 9 |
| .52–54 | | | | 1 | | | 3 | | | | | 4 |
| | 1 | 15 | 65 | 358 | 871 | 976 | 755 | 365 | 79 | 13 | 2 | 3,500 |

### 12. DENSITY OF COB AND THICKNESS OF KERNEL.

It was found in Table 4 that the thickness of kernel was not directly correlated with the circumference of cob. In Table 8 it was shown that the weight of cob has no direct correlation with the thickness of kernel. Instead, the thicker kernels were found on cobs of moderate weight. The correlation between the density of cob and thickness of kernel is expressed by the factor —.0514 ± .0114. It indicates a very slight tendency for thick kernels to be found on cobs of moderate density.

TABLE 12.—*Correlation between density of cob, subject; and thickness of kernel (number in 10 centimeters), relative.* ($r = -.0514 \pm .0114$.)

| Density of cob (factor). | Number of kernels in 10 centimeters. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | Totals |
| .12–.14 | | | | | | | | | 1 | | | | | | | 1 |
| .14–.16 | | | | | | | | | | | | | | | | |
| .16–.18 | 1 | | | | | 1 | 1 | | | | | | | | | 3 |
| .18–.20 | | | | | 2 | | 5 | 3 | 2 | | | | | | | 12 |
| .20–.22 | | | 1 | 3 | 3 | 9 | 12 | 5 | 7 | 9 | 1 | 1 | 2 | | | 53 |
| .22–.24 | | 1 | 2 | 3 | 6 | 10 | 16 | 28 | 22 | 10 | 8 | 2 | 1 | | | 109 |
| .24–.26 | | | 3 | 9 | 19 | 25 | 50 | 40 | 30 | 27 | 15 | 6 | 3 | 1 | | 228 |
| .26–.28 | | 2 | 2 | 6 | 17 | 43 | 61 | 69 | 65 | 38 | 24 | 13 | 2 | 1 | | 343 |
| .28–.30 | | | 4 | 10 | 32 | 60 | 75 | 82 | 66 | 42 | 30 | 11 | 7 | 1 | | 420 |
| .30–.32 | | 1 | 2 | 15 | 42 | 58 | 85 | 84 | 91 | 38 | 29 | 15 | 9 | 3 | 1 | 473 |
| .32–.34 | 1 | 1 | 5 | 15 | 30 | 62 | 101 | 89 | 63 | 56 | 28 | 8 | 3 | 1 | | 463 |
| .34–.36 | 1 | | 5 | 10 | 28 | 65 | 85 | 80 | 68 | 40 | 18 | 10 | 7 | 1 | | 418 |
| .36–.38 | | | 6 | 11 | 32 | 51 | 72 | 58 | 40 | 38 | 17 | 9 | 3 | 1 | | 338 |
| .38–.40 | | 1 | 2 | 5 | 28 | 34 | 55 | 58 | 44 | 25 | 8 | 5 | 1 | | | 266 |
| .40–.42 | | 1 | | 3 | 13 | 22 | 27 | 30 | 32 | 11 | 3 | | | 1 | | 143 |
| .42–.44 | | | 1 | 2 | 8 | 11 | 20 | 37 | 21 | 9 | 9 | 4 | 1 | | | 123 |
| .44–.46 | | | | 3 | 4 | 9 | 16 | 7 | 7 | 3 | 1 | 1 | | | | 51 |
| .46–.48 | | | | 3 | 1 | 8 | 6 | 3 | 5 | 3 | 3 | 1 | | | | 33 |
| .48–.50 | | | | | | 3 | 1 | 4 | | 1 | 1 | | | | | 10 |
| .50–.52 | | | 1 | | | 3 | 2 | 1 | 2 | | | | | | | 9 |
| .52–.54 | | | 1 | | | | 1 | | 2 | | | | | | | 4 |
| Totals | 3 | 7 | 35 | 98 | 265 | 474 | 691 | 678 | 568 | 350 | 195 | 86 | 39 | 10 | 1 | 3,500 |

## SUMMARY.

From the data which have been presented on the correlation of characters of cob to other ear characters of corn the following conclusions may be drawn:

1. The yield of grain per ear is strongly correlated with the circumference of cob.

2. There is practically no correlation between weight of individual kernel and the circumference of cob.

3. The depth of kernel is correlated to a moderate degree with cobs of small circumference.

4. The thickness of kernel is slightly correlated with cobs of small circumference.

5. The yield of grain per ear is correlated to a considerable degree with the weight of cob.

6. The weight of kernel is moderately correlated with cobs of low weight.

7. There is a very low correlation between depth of kernel and weight of cob. The heaviest cobs do not carry the deepest kernels.

8. A fair degree of correlation exists between the thickness of kernel and cobs of low weight.

9. The yield of grain per ear has a very slight correlation with low density of cob.

10. There is a moderate degree of correlation between weight of kernel and cobs of low density.

11. The depth of kernel is slightly correlated with density of cob.

TABLE 13.—*Summary table of variation constants in ears of corn and of correlation coefficients.*

| The ear as the unit. | Extremes. | Mean. | Standard deviation. | Coefficient of variation. |
|---|---|---|---|---|
| Circumference of cob, cm. . . . . . | 7–15 | 10.571 ±.0111 | 0.9773 ±.0079 | 9.24 ±.0748 |
| Weight of cob, gms. . . . . . . . . . . | 15–75 | 36.500 ±.0830 | .7289 ±.0590 | 19.97 ±.1680 |
| Density of cob, constant . . . . . . | .12–.54 | .328 ±.0006 | .0574 ±.0004 | 17.51 ±.1460 |
| Weight of grain, gms. . . . . . . . . . | 105–285 | 196.321 ±.2639 | 23.1466 ±.1875 | 11.79 ±.0968 |
| Depth of kernel, cm. . . . . . . . . . . | .7–1.9 | 1.248 ±.0015 | .1345 ±.0011 | 10.78 ±.0883 |
| Thickness of kernel (No. in 10 cm.) . . . . . . . . . . . . . . . . . . . . | 18–32 | 24.827 ±.0229 | 2.0137 ±.0163 | 8.11 ±.0657 |
| Weight of kernel (No. in 10 gm.) . . . . . . . . . . . . . . . . . . . . | 18–52 | 27.805 ±.0513 | 4.4994 ±.0364 | 16.18 ±.1344 |

| Characters. | Coefficient of correlation. |
|---|---|
| Circumference of cob and weight of grain per section. . . . . | .4118 ±.0095 |
| Circumference of cob and weight of kernel . . . . . . . . . . . . . | –.0185 ±.0114 |
| Circumference of cob and depth of kernel . . . . . . . . . . . . . | –.1789 ±.0110 |
| Circumference of cob and thickness of kernel . . . . . . . . . . | –.1053 ±.0113 |
| Weight of cob and weight of grain per section . . . . . . . . . | .3064 ±.0103 |
| Weight of cob and weight of kernel . . . . . . . . . . . . . . . . . | –.1837 ±.0110 |
| Weight of cob and depth of kernel . . . . . . . . . . . . . . . . . . | –.0747 ±.0113 |
| Weight of cob and thickness of kernel . . . . . . . . . . . . . . . | –.1500 ±.0111 |
| Density of cob and weight of grain per section . . . . . . . . | –.0728 ±.0113 |
| Density of cob and weight of kernel, . . . . . . . . . . . . . . . . . | –.1959 ±.0111 |
| Density of cob and depth of kernel . . . . . . . . . . . . . . . . . . | .1039 ±.0113 |
| Density of cob and thickness of kernel . . . . . . . . . . . . . . . | –.0513 ±.0114 |

12. The correlation between thickness of kernel and density of cob is very low and negative.

13. The coefficient of variability is much higher for weight of cob, density of cob, and weight of kernel than for the other characters.

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## WHOLE VS. CUT POTATO TUBERS FOR PLANTING ON IRRIGATED LAND.—I.[1]

L. C. Aicher.

In the United States practices in potato production are very largely sectional and often differ greatly. Probably the greatest difference is noted in the size and nature of the tuber piece planted. In some sections, the whole potato is planted; in others, only cut tubers. Some growers plant a large set, others plant a small one, and some plant culls. Only two of the great potato-producing sections, so far as the writer is able to learn, grow the same variety as a major crop. Climate and length of growing season are large determining factors in potato varietal selection and may also be contributing causes of some of the above mentioned methods of production.

There is considerable printed information available on potato production. Information tending to establish rather definitely the size of tuber piece to plant for the most economical production of the Irish potato, however, is limited and sectional. Practically all the information which is available has to do with potato production under humid or subhumid conditions. The experiments here reported deal entirely with the potato under irrigation.

These experiments were begun on the Aberdeen Branch Experiment Station at Aberdeen, Idaho, in 1913. In 1912 suitable seed stock was grown for the work. As the station work became better organized, more time and money were spent in obtaining data which

[1] Contribution from the Idaho Agricultural Experiment Station. Received for publication February 9, 1917. This is the first of two papers on the use of whole or cut potato tubers of various weights for planting on irrigated land, with reference to the total yield and the yield of marketable tubers. The work here described was performed on the Aberdeen substation. The second paper, which appears elsewhere in this issue, describes similar experiments conducted at the Gooding substation by J. S. Welch.

at first were not taken. It is realized that still further information would be highly desirable.

## Outline of the Experiment.

The Idaho Rural potato was used in this experiment. This variety is now supposed to be of the same stock as the Charles Downing. It it a flattened, oval-oblong, very smooth, medium-sized tuber with shallow eyes and white, creamy skin. The sprout is white, with tips slightly colored.

The set, or seed piece, as the terms are here used, is the portion of the tuber used in planting. The experiment was planned to include maximum, optimum, and minimum sized seed pieces. Tubers weighing approximately 8 ounces, 4 ounces, and 3 ounces each were used. A portion of each lot was planted whole, others were halved, and still others were quartered. The halved pieces were obtained by cutting the tuber lengthwise, care being taken to divide it into equal parts. The quartered seed was obtained by cutting the tuber lengthwise and then crosswise, making the quarters as uniform in size as possible. No attempt was made to have a definite number of eyes on each piece. Each whole tuber was first examined for external indications of disease. A thin slice then was cut off the stem end of the tuber as a further precaution against planting diseased stock. All tubers showing brown discoloration were discarded.

In 1913 and 1914 the seed potatoes were given the formaldehyde treatment (1 pint of formaldehyde to 25 gallons of water). The tubers were soaked in this solution for two hours. In 1915 and 1916 the bichloride treatment was given (4 ounces of bichloride of mercury to 30 gallons of water). The tubers were soaked 1½ hours. Those which were to be planted whole were treated after the stem ends had been examined for discoloration. Tubers which were to be cut were treated after cutting, to avoid reinfection of disease if any was met in cutting.

Care was taken to get tubers of the proper size for each experiment. A variation of a half ounce was permitted in the selection of the 8-ounce lot, while a variation of but a quarter ounce was permitted in the selection of the 3-ounce and 4-ounce tubers. The average weights in each lot were rigidly maintained.

The soil on the Aberdeen substation is a sandy clay loam. The 1913 crop was planted on land which was cleared of sagebrush two years previous and had produced two successive crops of wheat. The 1914 crop was planted on land which had produced three suc-

cessive crops of wheat and which was manured in the fall before the potatoes were planted. The 1915 crop was planted on land which produced a crop of field peas harvested for seed and which had previously been in wheat for three successive years. This land was manured the fall before the peas were planted. The 1916 crop was planted on land that had been in alfalfa three years and previous to that in wheat two years.

Furrows were opened with a shovel plow and the sets dropped by hand and covered with a "crowder." The rows were 33 inches apart, 6 rows composing the unit of a twentieth acre. The sets were planted 16 inches apart in the row and 4 inches deep. A brass chain with strings tied at 16-inch intervals served as a guide to the planters, thus insuring accurate placement of each tuber set. This method of planting proved very satisfactory.

Three or four irrigations and cultivations were given during the growing season, the number of irrigations given depending upon the seasonal precipitation and other climatic factors. Cultivation always followed irrigation except when the vines were large enough to shade the ground.

In 1915 and 1916 counts were taken on the percentage of stand and number of stalks per hill.

The yields of marketable and cull tubers were taken each year during the 4-year period. These data were obtained by hand sorting in 1913 and sorting over a specially prepared 2-inch screen in 1914, 1915, and 1916. In connection with this part of the experiment, the number of tubers in a bushel of the marketable and a bushel of the cull tubers was determined in 1915 and 1916, in order to arrive at a definite conclusion relative to the sizes of tubers produced by the various sizes of tuber sets and their average weight.

The crop was harvested with a standard type of power potato digger. Each plat was stored in the cellar until all were dug. The various lots were then sorted and calculations made.

## Results.

The sprouting and emergence period varied almost directly with the size and kind of set planted. The plants from the 8-ounce, 4-ounce, and 3-ounce whole tubers appeared first and in the order here mentioned. The next plants to appear came from the 8-ounce halved tubers. The plants from the 4-ounce and 3-ounce halved and 8-ounce quartered tuber sets appeared in the next 24 to 48 hours. The plants from the 4-ounce and 3-ounce quartered tubers were the

last to appear, the latter appearing from two to four days later than the plants from the 8-ounce whole tubers.

The sprouting and emergence period varied considerably from year to year, depending upon climatic conditions and the condition of the soil. A moist, warm soil was conducive to quick growth. A dry, warm soil retarded the growth of the smaller cut-tuber pieces but only slightly affected the emergence of the plants from the whole tubers. The early growth of the plants from the large whole tubers was least affected by the soil moisture content and the physical condition of the soil. Cold soil and cold weather retarded the growth of the plants from the whole and the cut tubers, but the latter seemed most affected.

Table 1 shows that the stand from the whole and halved tubers was excellent. There was, however, a severe loss in stand from the quartered tuber sets. The loss in stand from the 8-ounce and 4-ounce quartered tubers was 11 percent, while the loss from the 3-ounce quartered tubers was almost 18 percent. This loss is attributed to the inability of the plants from the small tuber sets to overcome adverse climatic and soil conditions, and to a possible lack of eyes on many of the small sets. The Idaho Rural potato has from 8 to 10 eyes, rarely 11, and 6 or more of these eyes are on the bud-end half of the potato. When this tuber is quartered without regard to the placement of the eyes, the stem-end quarters may have one or more eyes or sometimes none at all.

The average number of stalks per hill, as determined by actual count, varied directly with the size of the tuber set, in each respective lot of whole, halved, and quartered tubers. The 4-ounce whole tubers produced a greater number of stalks per hill than the 8-ounce halved tubers, which are really 4-ounce sets. This is due to the greater number of eyes on the whole tuber. The 4-ounce halved set produced more stalks per hill than the 8-ounce quartered tubers, for the same reason, both being 2-ounce sets. The 4-ounce quartered set produced the same number of stalks as the 3-ounce quartered tuber. This is due to the sets being very nearly the same size and having about the same number of eyes. Table 1 shows that the whole tubers produced almost twice as many stalks per hill as the halved sets and that the halved sets produced almost twice as many stalks per hill as the quartered sets.

Practically every eye on the 8-ounce whole, halved, and quartered tuber sets produced stalks, as will be noted by comparing the number of stalks per hill and the number of eyes per tuber on the Idaho

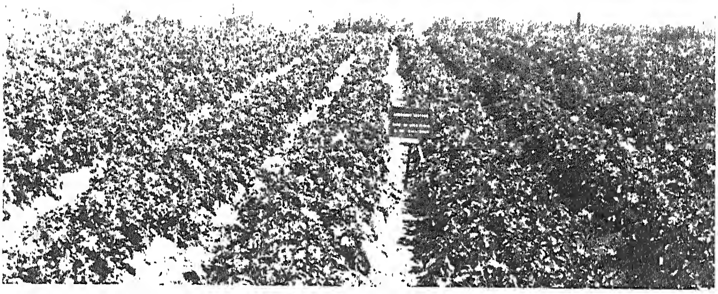


FIG. 1. View of plat planted with quartered 8-ounce potato tubers in 1916.

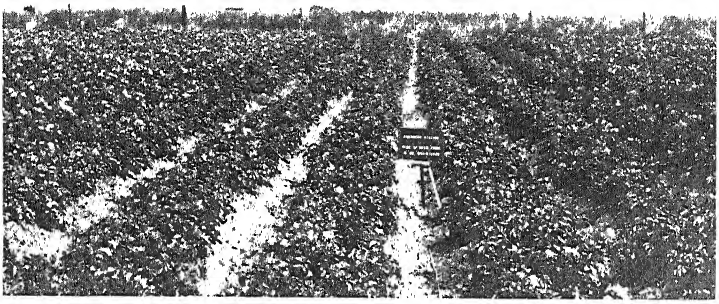


FIG. 2. View of plat planted with quartered 4-ounce potato tubers in 1916.

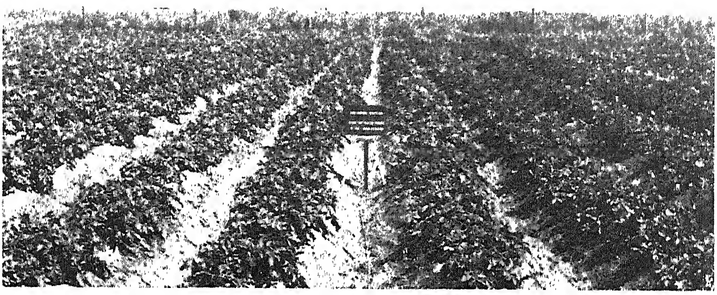


FIG. 3. View of plat planted with quartered 3-ounce potato tubers in 1916.

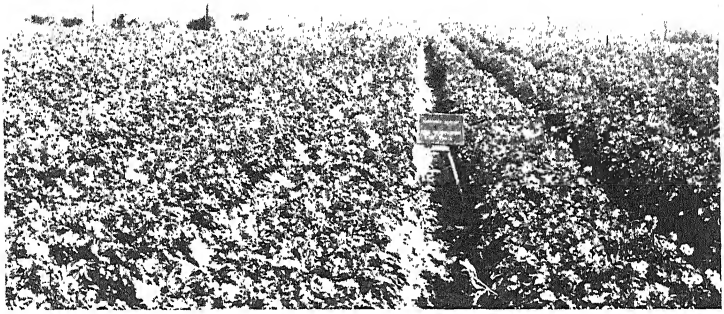


FIG. 1. View of plat planted with whole 8-ounce potato tubers in 1916.

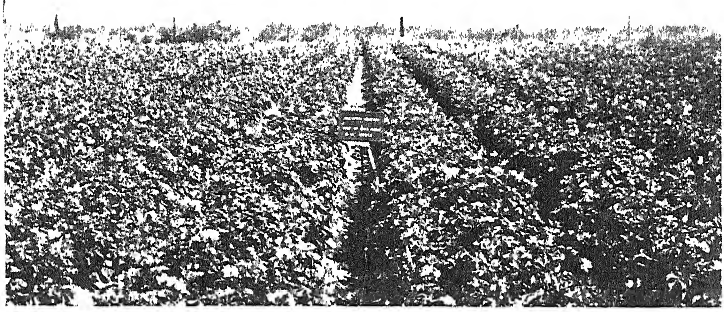


FIG. 2. View of plat planted with whole 4-ounce potato tubers in 1916.

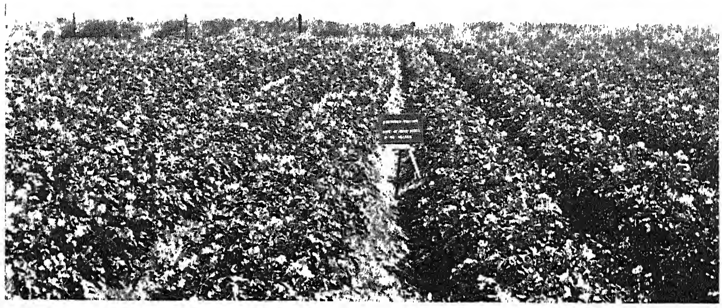


FIG. 3. View of plat planted with halved 4-ounce potato tubers in 1916.

Rural potato. The earlier sprouting bud-eye on the larger sets does not grow to the exclusion of growth of the other eyes of the tuber. The Idaho Rural potato is not given to producing a master sprout. If this potato, by breeding or selection, could be made to grow a master sprout the undesirable features resulting from planting whole tubers would be eliminated. The size of the set determines very largely how many eyes will produce stalks, for the larger the set the more plant food there is available and the greater the stimulus to each eye to produce a plant. The 4-ounce and 3-ounce whole tubers have just as many eyes as the 8-ounce tubers, but the eyes on the small tubers are not as well developed. Table 1 shows that the 8-ounce whole tubers produced 8.67 stalks per hill, whereas the 4-ounce and 3-ounce whole tubers produced but 5.41 and 4.82 stalks per hill, respectively. These stalks produce tubers and it is this fact which has such a large bearing upon the percentage of marketable tubers from the whole, halved, and quartered seed. These percentages are given in Table 1.

TABLE 1.—*Average stand, number of stalks per hill, total yield, yield of marketable tubers, and size of marketable and cull tubers recorded in an experiment to determine the effect of planting whole or cut potatoes of various sizes on irrigated land at the Aberdeen substation, Aberdeen, Idaho, 1913 to 1916, inclusive.*

| Description of tuber set planted. | Stand.[a] | Stalks per hill.[a] | Yield per acre. | | Percentage of marketable tubers. | Number of tubers per bushel.[a] | | Weight per tuber.[a] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Total. | Marketable. | | Marketable. | Culls. | Marketable. | Culls. |
| | *Percent.* | | *Bushels.* | *Bushels.* | | | | *Ounces.* | *Ounces.* |
| 8-oz. whole | 99.91 | 8.67 | 392.9 | 200.6 | 52.6 | 209 | 504 | 4.6 | 1.8 |
| 8-oz. halved | 99.97 | 4.71 | 333.5 | 210.5 | 65.2 | 196 | 439 | 4.9 | 2.1 |
| 8-oz. quartered | 89.28 | 2.63 | 314.0 | 218.2 | 69.1 | 152 | 410 | 5.7 | 2.3 |
| 4-oz. whole | 99.99 | 5.41 | 368.7 | 171.0 | 46.3 | 179 | 463 | 5.3 | 2.0 |
| 4-oz. halved | 99.99 | 2.98 | 332.9 | 220.1 | 66.1 | 171 | 418 | 5.7 | 2.2 |
| 4-oz. quartered | 89.31 | 1.71 | 322.7 | 250.9 | 77.4 | 152 | 414 | 6.2 | 2.3 |
| 3-oz. whole | 100.00 | 4.82 | 361.7 | 201.1 | 54.2 | 196 | 449 | 4.9 | 2.1 |
| 3-oz. halved | 98.87 | 2.64 | 355.5 | 253.8 | 68.8 | 162 | 417 | 5.9 | 2.3 |
| 3-oz. quartered | 82.19 | 1.72 | 262.7 | 201.5 | 78.0 | 170 | 412 | 5.6 | 2.2 |
| *Summary.* | | | | | | | | | |
| Whole | 99.97 | 6.30 | 374.4 | 191.0 | 51.0 | 194 | 472 | 4.9 | 1.9 |
| Halved | 99.61 | 3.44 | 340.6 | 228.1 | 66.7 | 176 | 424 | 5.5 | 2.2 |
| Quartered | 86.92 | 2.02 | 299.8 | 223.5 | 71.5 | 158 | 412 | 5.8 | 2.2 |

[a] Average for two years only (1915 and 1916).

Whole tubers invariably produced a larger and more plentiful growth of top than the cut pieces. This growth was proportional to

the size of the whole, halved, and quartered sets, respectively. Plates 5 and 6 show clearly the variations in growth. The large and vigorous growth from the large sets is due to the better start given the plants by the greater supply of food available; to the greater proportion of eyes producing stalks; and to the fact that the greater supply of natural moisture in the larger sets is not exhausted so rapidly. Unless the soil is in good condition, the small set dries out before the plant can get sufficient moisture from the soil to sustain growth. Some of the loss in stand from the quartered small tuber sets was due to unfavorable soil conditions. The top growth from the 3-ounce quartered sets was the least vigorous and the number of stalks per hill was the lowest of all the lots.

The whole tuber sets in each lot invariably produced the largest total yield of potatoes per acre. The average difference in yield between the whole and the halved tuber sets was 33.8 bushels per acre, while the average decrease in yield from halved to quartered sets was 40.8 bushels per acre. The whole-tuber plats outyielded the quartered-set plats on the average by 74.6 bushels per acre. The total yield from the 8-ounce whole tubers averages 28 bushels per acre more than the yield from the 4-ounce and 3-ounce whole tubers. On the other hand, the whole tuber sets have invariably yielded the smallest percentage of marketable potatoes per acre.

The total yield per acre, the yield per acre of marketable tubers, and the percentage of marketable tubers recorded in Table 1 are 4-year averages. The 8-ounce whole tubers produced 52.6 percent of marketable tubers, whereas 78 percent of the crop from the 3-ounce quartered sets was marketable. The 3-ounce quartered sets have always produced the smallest yield in bushels per acre and the highest percentage of marketable tubers. The decrease in yield is due in great measure to the 18 percent loss in stand in the 3-ounce quartered plats. With this great handicap, the 3-ounce quartered sets maintained a small increase in yield per acre of marketable tubers over the 8-ounce, 4-ounce and 3-ounce whole sets. The 8-ounce and 4-ounce halved and quartered sets and the 3-ounce halved sets all yielded a much greater number of bushels of marketable tubers per acre than any of the lots of whole seed or the 3-ounce quartered sets. The percentage of marketable tubers increased as the size of the set decreased. This is due in part to the smaller number of stalks per hill, to the smaller numbers of tubers per hill, and to the greater growth per tuber in the hills from the smallest sets. Whole sets produced more tubers per hill than cut sets and the average size of

the tuber was much smaller. The larger the set the greater the number of tubers produced and the smaller the average weight per tuber. This is due to the greater number of stalks per hill from the large sets, the greater competition for moisture and food, and the greater number of tubers produced per hill.

The data recorded in the experiment are summarized in Table 1.

## Summary

1. Whole tuber sets sprouted and the plants came up more quickly than those from cut tubers.

2. Whole tuber sets produced a larger and more plentiful top growth than cut tuber sets.

3. The vigor and size of the plant increased as the size of the set increased.

4. The number of stalks per hill increased directly as the size of the set increased.

5. The loss in stand from planting whole and halved tubers averaged less than 1 percent, while the loss in stand from planting quartered tubers averaged almost 13 percent.

6. The earlier sprouting bud eye of the Idaho Rural potato does not grow to the exclusion of the other eyes of the tuber.

7. The total yield from whole tubers was 14.4 percent more than from cut tubers.

8. Cut tubers yielded 18 percent more marketable potatoes per acre than whole tubers.

9. The percentage of marketable tubers increased as the size of the set decreased.

10. The larger the set the greater was the number of tubers produced and the smaller the average weight per tuber.

Aberdeen Substation,
Aberdeen, Idaho.

# WHOLE VS. CUT POTATO TUBERS FOR PLANTING ON IRRIGATED LAND.—2.[1]

JOHN S. WELCH.

The production of potatoes on the irrigated lands of southern Idaho is an extensive and profitable industry. Growers generally are agreed upon certain methods of procedure in the production of potatoes under irrigation, but there is a widespread difference of opinion among them relative to the use of whole and cut tubers for planting. Prominent growers unqualifiedly recommend the planting of whole tubers and argue that such a procedure results in better stands, earlier development, greater yields, and greater profits. Other growers equally as prominent reason that the old practice of cutting the tubers into a number of pieces is productive of best results under the conditions which prevail on most irrigated farms.

## REVIEW OF THE LITERATURE.

In reviewing the literature of the subject it seems best to mention only conclusions based directly on experimental data.

S. Johnson[2] concluded after four years of experimental work that whole tubers produce a greater total yield and also a greater yield of unmarketable potatoes than cut tubers.

D. D. Johnson[3] found that whole tubers produced a greater number of vigorous stalks per hill than halved or quartered tubers, but that the increased number of stalks did not produce a relatively greater yield of potatoes.

Taft[4] grew two varieties of potatoes from tubers planted whole and cut into halves, quarters, and eighths. He found halved tubers to be the most desirable when considered from the standpoint of net profit per acre.

[1] Contribution from the Idaho Agricultural Experiment Station. Received for publication February 21, 1917.

[2] Johnson, Sam'l. Potatoes, roots, fertilizers and oats. Mich. Agr. Expt. Sta. Bul. 46. 1889.

[3] Johnson, D. D. Potato culture and fertilization. W. Va. Agr. Expt. Sta. Bul. 20. 1892.

[4] Taft, L. R. Potato tests. Mich. Agr. Expt. Sta. Bul. 85. 1892.

Harwood and Holden[5] grew four varieties in an experiment to determine the relative value of whole and cut tubers for planting. With three of the varieties, planting whole tubers produced the greater yield of marketable potatoes. In every case the whole tubers produced the greater yield of unmarketable potatoes.

Plumb[6] found that planting halved tubers produced a greater number and a greater weight of marketable potatoes per hill than planting whole tubers; that whole tubers produced nearly twice as many unmarketable potatoes per hill as the halved tubers; that whole tubers produced a greater total weight of potatoes per hill; and that the potatoes grown from halved tubers were of a greater average size.

## Experimental Data.

In order to obtain data that would help to settle questions that arise in the irrigated sections of Idaho relative to the advisability of using whole or cut potatoes for planting, the following experimental work was conducted at the Gooding Substation during 1914, 1915, and 1916. Because of the uniformity of the results obtained, it is thought necessary to present in this paper only the average results of the three years' work.

Each season the test was conducted on eight plats of two rows each, with an average of 110 hills per row. The sizes of tuber pieces planted were as follows: 8-ounce to 10-ounce tubers, whole, halved, and quartered; 4-ounce to 6-ounce tubers, whole, halved, and quartered; and 2-ounce to 3-ounce tubers, whole and halved.

The soil on which the experiment was conducted is a uniform medium clay loam. Previous to the summer of 1909 it was covered with a rank growth of sagebrush. After being cleared and before being cropped to potatoes, it had produced small grains and legumes and had been given applications of barnyard manure. In preparation for potato growing the land was fall-plowed and left rough over winter. In the early spring it was worked down to conserve as much as possible of the winter precipitation until planting time.

The Idaho Rural variety was used exclusively. Stuart[7] classifies this variety with the Green Mountain group, which he describes as follows:

[5] Harwood, P. M., and Holden P. G. Potatoes: Amounts of seed. Mich. Agr. Expt. Sta. Bul. 93. 1893.

[6] Plumb, C. S. Experiments in growing potatoes. Tenn. Agr. Expt. Sta. Bul., vol. 3, no. 1. 1890.

[7] Stuart, William. Group classification and varietal descriptions of some American potatoes. U. S. Dept. Agr. Bul. 176. 1915.

Vines large, strong, healthy and well branched. Stems nearly upright in early stages of growth but gradually assuming a spreading habit toward the latter end of the season. Flowers white, abundant, rarely producing seed balls except under very favorable soil and climatic conditions. Tubers broadly roundish-flattened to distinctly oblong-flattened; ends usually blunt, especially the seed end; eyes medium in number, rather shallow with strong bud-eye cluster; skin dull creamy white, more or less netted; frequently with russet-colored splashes toward the seed end; sprouts rather short and stubby.

The tubers used for planting were bright, well-kept stock and true to type. The selections for size were made by weighing. In halving, the tubers were cut lengthwise (from seed end to stem end); in quartering they were first cut lengthwise and then crosswise. Planting was done by hand immediately after cutting. The sets were planted in hills 18 to 20 inches apart in rows 3.5 feet apart.

All plats were cultivated and irrigated exactly alike. The water was applied in a small stream running in a comparatively deep furrow between rows. On the average, three irrigations per season were given. All harvesting was done by hand. Potatoes which passed through a 2-inch mesh screen were classed as culls. The number of stalks and tubers per hill was estimated from data obtained by counting carefully the plants and tubers in 50 hills of each plat. All records in the tables are from actual weighings. The rates of planting, the stands obtained, and the number of days from planting to emergence are shown in Table 1.

TABLE 1.—*Rate of planting, stands, and number of days from planting to emergence recorded in an experiment to determine the relative merits of tubers of various sizes and of whole and cut tubers for planting.*

| Size and portion of tuber planted. | Rate of planting per acre. | Stand. | Time from planting to emergence. |
|---|---|---|---|
| | *Pounds.* | *Percent.* | *Days.* |
| 8 to 10 ounces, whole | 5,000 | 93.28 | 24 |
| 8 to 10 ounces, halved | 2,500 | 95.69 | 24 |
| 8 to 10 ounces, quartered | 1,250 | 87.34 | 27 |
| 4 to 6 ounces, whole | 2,800 | 96.06 | 24 |
| 4 to 6 ounces, halved | 1,400 | 91.22 | 27 |
| 4 to 6 ounces, quartered | 700 | 90.39 | 28 |
| 2 to 3 ounces, whole | 1,400 | 93.95 | 27 |
| 2 to 3 ounces, halved | 700 | 92.50 | 28 |

The cost of producing a crop of potatoes must be taken into account in ascertaining the relative efficiency of production methods. As the price of good seed potatoes at planting time is usually high, their cost becomes one of the most important factors in determining the cost of production. The number of pounds of the various seed pieces

required to plant an acre is, therefore, shown in Table 1. Since 9,000 hills per acre are usually planted on the irrigated lands of this section, that number was used in making the computations. It is clear that in computing the net returns per acre, especially from planting whole tubers, the quantity planted per acre must be reckoned with.

Except in the case of the potatoes weighing 8 to 10 ounces, the whole tubers produced a slightly better stand than the halved tubers; in all cases the halved tubers produced a better stand than the quartered tubers.

One of the arguments used by those who advocate the planting of whole tubers is that this procedure results in a shortening of the time intervening between planting and emergence and thus insures the earlier development of the crop. It is apparent from the data recorded in Table 1 that the time from planting to emergence depends entirely on the size of the seed piece, and not at all on whether it is whole, halved, or quartered.

TABLE 2.—*Number of stalks, number of tubers, and number of marketable tubers and culls per hill produced from tubers of various sizes planted whole, halved, and quartered.*

| Size and portion of tuber planted. | Number of stalks per hill. | Number of tubers per hill. | Number of tubers per stalk. | Number of marketable tubers per hill. | Number of culls per hill. |
|---|---|---|---|---|---|
| 8 to 10 ounces, whole | 8.9 | 22.7 | 2.6 | 7.3 | 15.4 |
| 8 to 10 ounces, halved | 5.6 | 17.2 | 3.1 | 8.2 | 9.0 |
| 8 to 10 ounces, quartered | 2.9 | 12.5 | 4.3 | 7.2 | 5.3 |
| 4 to 6 ounces, whole | 7.4 | 20.8 | 2.8 | 8.1 | 12.7 |
| 4 to 6 ounces, halved | 4.0 | 15.0 | 3.7 | 8.0 | 7.0 |
| 4 to 6 ounces, quartered | 2.3 | 12.0 | 5.2 | 7.4 | 4.6 |
| 2 to 3 ounces, whole | 5.2 | 16.4 | 3.2 | 7.6 | 8.8 |
| 2 to 3 ounces, halved | 2.9 | 12.4 | 4.3 | 6.4 | 6.0 |

Recommendations for the use of whole tubers for planting seem also to be based in part upon the belief that, when the tuber is planted whole, one large sprout will grow from the terminal bud or seed end and will develop at the expense of other sprouts, producing one large, vigorous stalk per hill. Data recorded in Table 2 do not support that belief. Nearly all the eyes grow. The whole tubers produced nearly twice as many stalks per hill as the halved tubers and the halved tubers nearly twice as many stalks as the quartered tubers. The number of tubers produced per hill decreased with the number of stalks per hill, although the decrease was not directly in proportion. The number of tubers per stalk increased as the number of

stalks per hill decreased. The number of cull potatoes per hill was in almost direct proportion to the number of stalks per hill.

As would be expected from the data shown in Table 2, the plantings which produced the fewest culls produced tubers of greatest average size. In every size of tubers planted (8- to 10-ounce, 4- to 6-ounce, and 2- to 3-ounce), the whole tubers produced smaller potatoes than the halved and the halved tubers produced smaller potatoes than the quartered.

TABLE 3.—*Average weight of all tubers, and of marketable tubers and culls separately, produced from planting tubers of various sizes planted whole, halved, and quartered.*

| Size and portion of tuber planted | Average size of tubers. | | | Weight of tubers per hill. | | | Percentage marketable. |
|---|---|---|---|---|---|---|---|
| | All. | Marketable. | Culls. | All. | Marketable. | Culls. | |
| | *Ounces.* | *Ounces.* | *Ounces.* | *Pounds.* | *Pounds.* | *Pounds.* | |
| 8 to 10 ounces, whole | 2.6 | 4.7 | 1.4 | 3.67 | 2.28 | 1.39 | 62.12 |
| 8 to 10 ounces, halved | 3.5 | 5.7 | 1.6 | 3.76 | 2.90 | .86 | 77.12 |
| 8 to 10 ounces, quartered | 4.3 | 5.9 | 2.2 | 3.36 | 2.65 | .71 | 78.87 |
| 4 to 6 ounces, whole | 2.8 | 4.6 | 1.6 | 3.56 | 2.33 | 1.23 | 65.45 |
| 4 to 6 ounces, halved | 3.5 | 5.0 | 2.0 | 3.33 | 2.50 | .83 | 75.05 |
| 4 to 6 ounces, quartered | 3.8 | 4.8 | 2.1 | 2.85 | 2.23 | .62 | 78.25 |
| 2 to 3 ounces, whole | 3.2 | 4.7 | 1.9 | 3.25 | 2.24 | 1.01 | 68.09 |
| 2 to 3 ounces, halved | 4.0 | 6.0 | 1.9 | 3.11 | 2.41 | .70 | 77.49 |

Any practice in potato culture should be judged according to the yield of marketable potatoes obtained by following it. It will be noted that 8-ounce to 10-ounce whole tubers produced a smaller yield of marketable potatoes per hill than either the halved or the quartered tubers and that the halved tubers produced a greater yield of marketable potatoes per hill than the quartered ones. The whole tubers weighing 4 to 6 ounces produced a smaller yield of marketable potatoes than the halved, but a slightly larger yield than the quartered tubers. Even with tubers weighing 2 to 3 ounces, the halved outyielded the whole tubers in yield of marketable potatoes.

From the standpoint of total yield, the greatest weight was grown from 8- to 10-ounce tubers halved, the next greatest weight from 8- to 10-ounce whole tubers, and the next from 4- to 6-ounce whole tubers. The smallest total yield was produced from 4- to 6-ounce tubers quartered.

The yields are shown in Table 4 in pounds per hill. On that basis the variations do not seem great. When it is remembered, however. that a difference of 1 pound per hill is equivalent to about 9,000 pounds per acre, these seemingly small variations become very significant.

The more important data in Tables 2 and 3 are summarized in Table 4 so that they may be more conveniently studied.

TABLE 4.—*Summary of principal data on an experiment with planting whole and cut tubers of various sizes.*

| Size and portion of tuber planted. | Number of stalks per hill. | Number of tubers per hill. | Average weight of tubers. | Total weight of tubers per hill. | Total weight of marketable tubers per hill. | Percentage of tubers marketable. |
|---|---|---|---|---|---|---|
| | | | *Ounces.* | *Pounds.* | *Pounds.* | |
| 8 to 10 ounces, whole | 8.9 | 22.7 | 2.6 | 3.67 | 2.28 | 62.12 |
| 8 to 10 ounces, halved | 5.6 | 17.2 | 3.5 | 3.76 | 2.90 | 77.12 |
| 8 to 10 ounces, quartered | 2.9 | 12.5 | 4.3 | 3.36 | 2.65 | 78.87 |
| 4 to 6 ounces, whole | 7.4 | 20.8 | 2.8 | 3.56 | 2.33 | 65.45 |
| 4 to 6 ounces, halved | 4.0 | 15.0 | 3.5 | 3.33 | 2.50 | 75.05 |
| 4 to 6 ounces, quartered | 2.3 | 12.0 | 3.8 | 2.85 | 2.23 | 78.25 |
| 2 to 3 ounces, whole | 5.2 | 16.4 | 3.2 | 3.25 | 2.24 | 68.09 |
| 2 to 3 ounces, halved | 2.9 | 12.4 | 4.0 | 3.11 | 2.41 | 77.49 |

It appears that a definite relation exists between the number of stalks per hill, the number of tubers per hill, the average size of the tubers, and the percentage of marketable tubers; that the number of tubers per hill decreases with the number of stalks per hill and that this decrease is accompanied by an increase in the average size of the tubers and in the percentage of marketable tubers.

The best yields were obtained with a medium number of tubers per hill. It is conceivable that, if sufficient plant food were available, all of the tubers which set might be made to reach marketable size. In that case hills which set the greatest number of tubers would produce the greatest yields. If this condition could be realized one could assume that the procedure which induced the greatest set per hill would be the most profitable. A hill of eight stalks has little if any greater root zone than one of two stalks and, therefore, it has no more plant food to draw upon. To provide that hill with sufficient plant food to develop all of its tubers, a very liberal use of commercial fertilizer would be necessary. Under present conditions on the average irrigated farm in this section it is doubtful if that practice would prove practicable. It must not be inferred, however, that the soil upon which this experiment was conducted was in a low state of fertility, for potatoes of the same variety growing within a few feet of the plats used in 1916 yielded 450 bushels per acre.

Most of the tubers produced on the experimental plats showed a small amount of rhizoctonia. Tubers from each plat were carefully examined to determine the relative amount of disease present. No

difference whatever could be noted between the potatoes grown from whole and those from cut tubers.

## Summary.

The experiments recorded here have been conducted for three years. The greatest possible care was taken to insure uniform soil conditions and to provide uniform irrigation and cultural methods. The results of the three years' work are in close agreement. Average results only are presented in this paper.

In general, planting whole tubers produced a better stand than cut tubers, but the increase in stand was not at all commensurate with the greater weight of tubers used in obtaining it.

The relative time from planting to emergence did not depend upon the use of whole or cut tubers. It was determined wholly by the size of the seed piece.

Whole tubers showed no tendency whatever to develop only one sprout from the seed end.

The number of tubers per hill decreased with the number of stalks per hill, but the number of tubers per plant increased as the number of stalks per hill decreased. The hills which had the greatest number of stalks invariably produced the greatest number of culls.

In every size planted, whole tubers produced smaller potatoes than halved and halved produced smaller potatoes than quartered tubers.

The greatest yield of marketable potatoes was produced from 8- to 10-ounce tubers halved. Very good yields, however, were produced by the 8-to 10-ounce quartered and the 4- to 6-ounce halved tubers. In every weight of tubers selected the whole tubers produced smaller yields of marketable potatoes than the cut tubers.

Under conditions which prevail on the average irrigated farm in southern Idaho, the planting of whole potatoes is not advisable.

Gooding Substation,
Gooding, Idaho.

# THE COMPARATIVE EFFICIENCY OF INDEXES OF DENSITY, AND A NEW COEFFICIENT FOR MEASURING SQUAREHEADEDNESS IN WHEAT.[1]

S. BOSHNAKIAN.

There are three types of compact wheats, the squarehead (*Triticum capitatum,* Schulz.), the club (*T. compactum,* Host.) and a third form, the squarehead-club, which will be referred to in this paper as *T. compacto-capitatum.* In figure 14 these three forms are represented by heads 4, 5, and 6, respectively. These are all classified generally as *T. compactum* and oftener called "club" in literature, but as they differ appreciably in form as well as in genetic behavior it is necessary to make distinctions between them. The object of this paper is first to analyze the comparative efficiency of the indexes of density in use at present; second, to suggest the use of a new coefficient to substitute for the present ways of measuring compactness, which do not bring out these differences; and third, to describe an instrument for measuring squareheadedness.

## 1. THE INDEXES OF DENSITY.

The index of compactness, known as the density coefficient, may be determined in several ways. The oldest in use in practical breeding was found by the formula

$$D_1 = \frac{L}{S}. \qquad \text{(Formula 1}a\text{)}$$

where $D_1$ = density according to formula 1;

$L$ = length of spike measured from the base of the head to the tip of the terminal spikelet; and

$S$ = number of spikelets.

The length of the head measured in this manner will vary according to the length of the terminal spikelet. When, for instance, density studies are to be made upon a population derived from a cross between a Polish and any of the club wheats, the use of this formula becomes anything but practicable, due to the length of the terminal spikelet of the Polish, which sometimes is as long as the

[1] Paper No. 61, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Received for publication January 10, 1917.

entire rachis of the club wheat. In taking data on *vulgare* wheats the use of formula 1, as will be pointed out later, does not introduce a very serious error.

To overcome this source of error another method came into use. By this method the index of density is found by dividing the length of the rachis (instead of the total length of the head) by the number of spikelets, thus:

$$D_2 = \frac{R}{S} \qquad \text{(Formula 2a)}$$

where $D_2$ = density found by formula 2*a*;
$R$ = length of rachis in mm.; and
$S$ = number of spikelets.

This formula expressed in percentage as

$$D_2\,\% = \frac{S \times 100}{R} \qquad \text{(Formula 2b)}$$

was suggested by Neergaard (1887). The latter formula, instead of showing how many millimeters of the rachis length on an average are shared by each spikelet, as does formula 2*a*, shows the expected number of spikelets per 100 mm. of rachis length.

A third and a more logical standard generally used at present consists in determining the average length of the rachis internode. It is found simply by dividing the length of the rachis by the number of internodes (which is always one less than the number of spikelets on the same head). This formula may be presented as

$$D_3 = \frac{R}{I} \qquad \text{(Formula 3a)}$$

where $D_3$ = density of formula 3*a*;
$R$ = length of the rachis in mm.; and
$I$ = number of rachis internodes.

Expressed in percentages,

$$D_3\,\% = \frac{I \times 100}{R} \qquad \text{(Formula 3b)},$$

which shows the average number of rachis internodes found in 100 mm. of the rachis length.

Derlitzki (1913) suggested that the true density of a head may be better represented by adding 1 to the percentage of density shown by formula 3*b* above, thus:

$$D_4\,\% = \frac{I \times 100}{R} + 1, \quad \text{or} \quad = D_3 + 1 \qquad \text{(Formula 4).}^{1}$$

His formula is a modification of that of Neergaard. The addition

of a unit to the number of internodes per 100 mm. rachis length is based upon the fact that no matter what portion of the rachis is taken the number of the spikelets in a given distance is always one more than the number of internodes. Each rachis internode terminates with a spikelet, but an additional spikelet without a rachis internode is always located at the base of the head just where the basal internode carrying its spikelet is articulated. It is the presence of the basal spikelet which in the calculation of density introduces the addition of a unit to the number of internodes which make up an imaginary spike of 100 mm. rachis length.

Derlitzki's theory appears to be very plausible, as it points out an error in Neergaard's formula which for many years was overlooked. But as the results obtained from the application of such formulæ in actual practice are of more interest than the theories themselves, one is justified in inquiring just how great the difference is between the two formulæ in question and, further, it is desirable to know how this difference compares with the errors which accompany the measuring of the material.

Derlitzki's formula, $\frac{I \times 100}{R} + 1$, may be represented as $X + 1$ by substituting the symbol $X$ for the value $\frac{I \times 100}{R}$. Substituting the value $I + 1$ for the number of spikelets on the head to be measured, Neergaard's formula (*2b*) may be expressed thus,[2]

$$\frac{(I+1) \times 100}{R} = \frac{I \times 100}{R} + \frac{100}{R} = X + \frac{100}{R}.$$

[2] The value $100/R$ is equal to $X/I$. The product of Neergaard's formula in reality is equal to the number of internodes in 100 mm. length plus that portion of that coefficient $\frac{(I \times 100)}{R}$ shared by one additional internode. Thus,

$$\frac{I \times 100}{R} + \frac{\frac{I \times 100}{R}}{I} = X + \frac{X}{I}.$$

For instance, take a head 80 mm. long, with 20 internodes. Then

$$I = 20,$$

$$R = 80,$$

$$X = \frac{I \times 100}{R} = \frac{2000}{80} = 25.$$

Density with formula *2b* equals

$$\text{either } X + \frac{100}{R} = 25.0 + \frac{100}{80} = 25.0 + 1.25 = 26.25,$$

$$\text{or } X + \frac{X}{I} = 25 + \frac{25}{20} = 25 + 1.25 = 26.25.$$

So we find that the difference between the old (2*b*) and the corrected (4) formula is

$$\left(X+\frac{100}{R}\right)-(X+1)=\frac{100}{R}-1.$$

Since the variable quantity in this last formula is $R$, the length of the rachis, the difference between the results by these two formulæ varies inversely with and depends solely upon the length of the rachis provided the number of internodes is constant.

Just how much this difference is for heads of various lengths is shown in the following table. Heads with 20 internodes and ranging in length from 20 mm. to 160 mm. have been used for illustration. The above number of internodes is taken for simplicity and also because nearly all wheats, especially the cultivated species, have a mean number of internodes fluctuating around that number.

TABLE 1.—*Density of heads of wheat of 20 internodes and varying in length from 20 to 160 mm., according to Derlitzki's and to Neergaard's formula.*

| Length of rachis in mm. $= (R)$. | Number of internodes per 100 mm. $= (X)$. | Density after Derlitzki's formula $(X+1)$. | Density after Neergaard's formula $\left(X+\frac{100}{R}\right)$. | Differences between two formulæ $\left(\frac{100}{R}-1\right)$. |
|---|---|---|---|---|
| 20 | 100.0 | 101.0 | 105.0 | 4.0 |
| 30 | 66.7 | 67.7 | 70.0 | 2.3 |
| 40 | 50.0 | 51.0 | 52.5 | 1.5 |
| 50 | 40.0 | 41.0 | 42.0 | 1.0 |
| 60 | 33.3 | 34.3 | 35.0 | .7 |
| 70 | 28.7 | 29.7 | 30.0 | .3 |
| 80 | 25.0 | 26.0 | 26.2 | .2 |
| 90 | 22.2 | 23.2 | 23.3 | .1 |
| 100 | 20.0 | 21.0 | 21.0 | .0 |
| 110 | 18.2 | 19.2 | 19.1 | .1 |
| 120 | 16.7 | 17.7 | 17.5 | .2 |
| 130 | 15.4 | 16.4 | 16.1 | .3 |
| 140 | 14.3 | 15.3 | 15.0 | .3 |
| 150 | 13.3 | 14.3 | 14.0 | .3 |
| 160 | 12.3 | 13.3 | 12.9 | .4 |

The results in the last column of Table 1 show that the differences of the two methods for heads 60 mm. or longer is less than 1 percent; for heads 5 cm. or shorter the difference varies from 1 to 4 percent.

The next questions that arise are: What is the amount of error in measuring wheats, and how do the differences between these two methods compare with that error? Length measurements in wheat are considered satisfactory if measured accurately to the millimeter. They cannot be measured to the tenth of a millimeter because: (1) The end of the rachis is not sharply marked. There is a region about

4 mm. long which belongs partly to the spikelet and partly to the rachis, and when the spikelet is broken off that region may go with the spikelet or may remain attached. A similar region exists at the base of the rachis. (2) A slight bending of the rachis may easily introduce an error of 1 to 2 mm., depending on the length of the head. (3) The personal error in observations is too great when dealing with such fine measurements to allow measurements of less than 1 mm. Errors of 0.5 mm. one way or the other are very easy to make when measurements are made with a reasonable degree of rapidity; errors greater than that are also made and when one measures a dozen heads on different occasions he will find that such errors can not be avoided because the material does not lend itself to finer measurements.

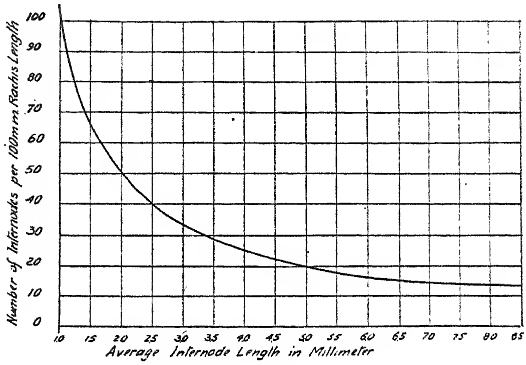



FIG. 11. Curve showing respective values of number of internodes in 100 mm. of rachis length and average internode length.

As length is measured to the nearest millimeter, that is, a deviation of 0.5 mm. in either direction, the differences in results introduced

TABLE 2.—*Errors in density determinations of wheat heads introduced by half-millimeter errors in measurements of heads of various length.*

| Length of heads in mm. | Results of formula 4 with +0.5 mm. error in the length measurement. | Results of formula 4 with —0.5 mm. error in the length measurement. | Differences of ±0.5 mm. error. | Differences of the two formulæ. |
|---|---|---|---|---|
| 20 | 98.5 | 101.5 | 3.0 | 4.0 |
| 30 | 68.8 | 66.6 | 2.2 | 2.4 |
| 40 | 51.6 | 50.4 | 1.2 | 1.5 |
| 50 | 41.4 | 40.6 | .8 | 1.0 |
| 60 | 34.6 | 34.0 | .6 | .7 |
| 70 | 29.7 | 29.3 | .4 | .4 |
| 80 | 26.1 | 25.8 | .3 | .2 |
| 90 | 23.4 | 23.1 | .3 | .1 |
| 100 | 21.1 | 20.9 | .2 | .0 |
| 110 | 19.3 | 19.1 | .2 | .1 |
| 120 | 17.7 | 17.6 | .1 | .2 |
| 130 | 16.4 | 16.3 | .1 | .3 |
| 140 | 15.3 | 15.2 | .1 | .3 |
| 150 | 14.4 | 14.3 | .1 | .3 |
| 160 | 13.5 | 13.5 | .0 | .4 |

by an error of 0.5 mm. will be determined. The same heads having 20 spikelets each shown in the first column of the preceding table will be used and the differences produced by this deviation will be compared with the differences of the two methods. The data are shown in Table 2.

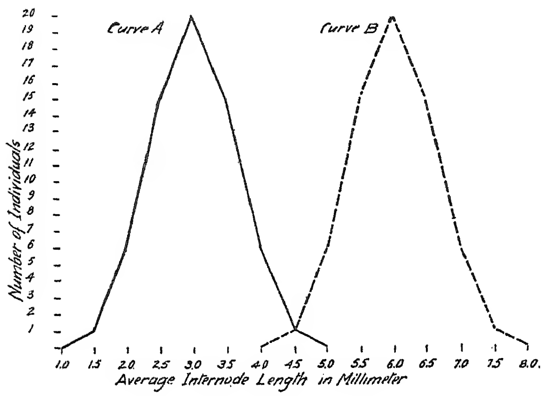



FIG. 12. Two identical frequency distributions plotted for the dense (curve A) and lax (curve B) classes.

It is seen from the last two columns of Table 2 that even a measurement to the nearest millimeter introduces a difference in the results which is almost as great as the difference between the two methods. So far as its results in actual practice are concerned, Derlitzki's formula hardly differs from the results obtained with Neergaard's formula.

In what respects do these two methods differ from methods 1 and 3? The question may best be answered by comparing the density figures obtained by these four methods. Since the last three methods represent the density per 100 mm. of rachis length, the first method will be used with the same standard, the formula being $\frac{S \times 100}{L}$ (formula 1*b*). The writer knows of only one case in which this formula has been used.

Table 3 shows the measurements of six types of heads shown in fig. 14.

The averages of the four methods are here used for comparison, but it should not be inferred that these averages represent the figures which show the true density.

The foregoing comparison shows that the least deviation from the averages of all four methods is found in the results obtained by formula 3*b*. The results of formula 1*b* are always below the averages, those of formula 2*b* and 4 always above, whereas those of formula 3*b* fluctuate slightly both above and below. In other words, the results by this last formula follow closely the average of the four formulæ. These figures show further that with the lax types the

difference between the four methods is not so great but becomes more and more pronounced with the denser forms.

TABLE 3.—*Measurements of six types of wheat heads, with densities calculated by various formulae and the deviation by each calculation from the average.*

| Data. | Type 1, Winter spelt (*T. spelta*). | Type 2, Amber Long-berry (*T. vulgare*). | Type 3, Early Red Chief, (*T. vulgare*). | Type 4, Extra Early Windsor, (*T. capitatum*). | Type 5, Little Club (*T. compactum*). | Type 6, Dale Gloria (*T. compacto-capitatum*). | Average error of the mean. |
|---|---|---|---|---|---|---|---|
| Length of head ($L$) | 94 | 83 | 67 | 81 | 46 | 42 | |
| Length of rachis ($R$) | 87 | 78 | 61 | 75 | 41 | 35 | |
| No of spikelets ($S$) | 20 | 20 | 18 | 20 | 19 | 20 | |
| No. of internodes ($I$) | 19 | 19 | 17 | 19 | 18 | 19 | |
| Percentage of density: | | | | | | | |
| Formula 1*b* | 21.3 | 24.1 | 26.9 | 24.7 | 41.3 | 47.6 | |
| Formula 2*b* | 23.0 | 25.6 | 29.5 | 26.7 | 46.3 | 57.1 | |
| Formula 3*b* | 21.8 | 24.3 | 27.8 | 25.3 | 43.9 | 54.3 | |
| Formula 4 | 22.8 | 25.3 | 28.8 | 26.3 | 44.9 | 55.3 | |
| Average | 22.2 | 24.8 | 28.2 | 25.7 | 44.1 | 53.6 | |
| Deviations from averages: | | | | | | | |
| Formula 1*b* | −0.9 | −0.7 | −1.3 | −1.0 | −2.8 | −6.0 | ±.923 |
| Formula 2*b* | +0.8 | +0.8 | +1.3 | +1.0 | +2.2 | +3.5 | ±.679 |
| Formula 3*b* | −0.4 | −0.5 | −0.4 | −0.4 | −0.2 | +0.7 | ±.156 |
| Formula 4 | +0.6 | +0.5 | +0.6 | +0.6 | +0.8 | +1.7 | ±.353 |

So far as these results show, formula 3*b* seems to be the best of the four methods.

It was shown that method 3 had two formulæ. The first (formula 3*a*) showed the average internode length, and the second (formula 3*b*) determined the density in terms of number of rachis internodes on a rachis 100 mm. long. Can both be used with equal efficiency?

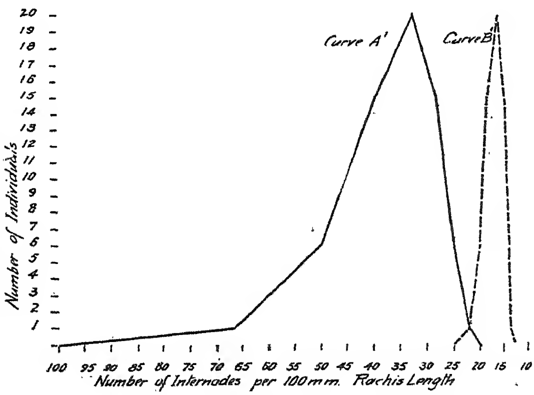



FIG. 13. Values of curves A and B in figure 12 expressed in terms of number of internodes per 100 mm. of rachis length.

If, as in the case of different standards of weights, measures, etc., with each increase of unit with one formula the figures of the other formula increase or decrease with the same increment, either can be used with equal efficiency. If this be the case the mathe-

matical curve showing the corresponding values will take the form of a straight line.

Plotting the figures obtained with both methods, a curve shown in figure 11 is obtained which is the expression of the formula $X = \frac{100}{Y}$. It is seen from the curve that the values obtained with the percentage basis give more weight to the denser forms, and less weight in the same proportion to the laxer types. This fact may be made clearer by comparing two normal frequency curves plotted in terms of average internode length (fig. 12) and the same values with their respective frequencies in terms of number of internodes per 100 mm. rachis length (fig. 13). The frequencies and corresponding classes and results of both standards are shown in Table 4.

TABLE 4.—*Frequencies in classes of average internode length and classes of number of internodes in 100 mm. in curves A and B (fig. 12) and curves A′ and B′ (fig. 13).*

| Curve *A* (fig. 12). | | Curve *A′* (fig. 13). | | | Curve *B* (fig. 12). | | Curve *B′* (fig. 13). | | |
|---|---|---|---|---|---|---|---|---|---|
| Classes of average internode length in mm. | Difference between classes, mm. | Classes of number of internodes in 100 mm.[a] | Difference between classes, mm. | Frequencies. | Classes of average internode length in mm. | Difference between classes, mm. | Classes of number of internodes in 100 mm.[b] | Difference between classes, mm. | Frequencies. |
| 1.5 | .. | 66.6 | 16.6 | 1 | 4.5 | .. | 22.2 | 2.2 | 1 |
| 2.0 | 0.5 | 50.0 | 10.0 | 6 | 5.0 | 0.5 | 20.0 | 1.8 | 6 |
| 2.5 | 0.5 | 40.0 | 6.7 | 15 | 5.5 | 0.5 | 18.2 | 1.6 | 15 |
| 3.0 | 0.5 | 33.3 | 4.8 | 20 | 6.0 | 0.5 | 16.6 | 1.2 | 20 |
| 3.5 | 0.5 | 28.5 | 3.5 | 15 | 6.5 | 0.5 | 15.4 | 1.1 | 15 |
| 4.0 | 0.5 | 25.0 | 2.8 | 6 | 7.0 | 0.5 | 14.3 | 1.0 | 6 |
| 4.5 | 0.5 | 22.2 | .. | 1 | 7.5 | 0.5 | 13.3 | .. | 1 |
| $M = 3.0 \pm .052$<br>$\sigma = .612 \pm .036$ | | $M = 34.82 \pm .682$<br>$\sigma = 8.093 \pm .482$ | | | $M = 6.0 \pm .052$<br>$\sigma = .612 \pm .036$ | | $M = 16.92 \pm .144$<br>$\sigma = 1.703 \pm .102$ | | |

[a] Equivalents of classes of curve *A* (fig. 12).
[b] Equivalents of classes of curve *B* (fig. 12).

The figures obtained above point out four differences in the use of the two formulæ, 3*a* and 3*b*:

1. A normal frequency curve with formula 3*a* gives a skew curve when plotted in terms of number of internodes per 100 mm., the skewness being toward the more lax classes. This is well shown by curves *A* and *A′* plotted in figs. 2 and 3. Curve *A* (fig. 12) is a symmetrical curve where the mode 3.0 coincides with the median, the center of the range. The median of curve *A′* (fig. 13) is at 44.4 but the mode is at 33.3, or 11.1 internodes towards the laxer classes.

2. On account of this skewness the mean density obtained with formula *3b* is always greater than the corresponding value of the mean obtained with formula *3a*. When the mean internode length of the frequency distribution represented by curve *A* is 3 mm. its corresponding value with formula *3b* should be 33.33 internodes per 100 mm. Calculation, however, shows 34.82 internodes, an increase of 1.49 internodes. With curve *B'*, where the range on the percentage basis is very small, the difference is not so great. The equivalent of 6 mm., the mean of curve *B*, is 16.66 internodes per 100 mm. The calculated mean is 16.92, which shows a difference of $+0.26$ internode.

3. Frequency curves of dense and lax types found by formula *3a* (fig. 12) show, when expressed with formula *3b*, an appreciably greater range of variation with denser wheats (fig. 13, curve *A*) and a much smaller range among laxer forms (fig. 13, curve *B*). While the ranges of variation of the two curves with formula *3a* are identical, these same curves plotted in terms of number of internodes per 100 mm. will show ranges of 44.4 and 8.9 internodes for curves *A* and *B* respectively. This gives the impression that the range of curve *A* is five times greater than that of curve *B*, which of course is erroneous.

4. Consequently, the standard deviation of formula *3b* tends to increase and decrease considerably as the figures of the classes increase or decrease. The standard deviations of curves *A* and *B* (formula *3a*) were found to be identical, that is, $0.612 \pm .036$ in both cases. As calculated for the other formula (*3b*) the standard deviations are $8.093 \pm .482$ and $1.703 \pm .102$ respectively, showing an appreciable difference of $7.390 \pm .492$ internodes.

TABLE 5.—*Variation and range of density in Dale Gloria and Amber Longberry wheats.*

| | Dale Gloria. | Amber Longberry. | Ratio of ranges. |
|---|---|---|---|
| Formula *3a*: | | | |
| Variation | 1.2 to 2.3 mm. | 3.0 to 5.4 mm. | |
| Range | 1.1 mm. | 2.4 mm. | 1:2.18 |
| Formula *3b*: | | | |
| Variation | 83.3 to 43.5 percent | 33.3 to 18.5 percent | |
| Range | 39.8 percent | 14.8 percent | 1:0.37 |

In nature, the range of variation and the standard deviation of length characters, such as those of internodes, spikes, and culms in wheat, decreases as the length of the character in question decreases. For instance, in comparing the range of variation of density of Dale

Gloria (type 6, fig. 14) and of Amber Longberry (type 2) with the two formulæ the results shown in Table 5 are obtained.

It is seen from the above actual case that the range of density of Amber Longberry is over twice that of Dale Gloria (formula 3*a*). On the other hand, as found on the percentage basis (formula 3*b*), the fact seems to be just the reverse. The figures of the percentage formula show that Dale Gloria has a range over two and one-half times that of Amber Longberry. Is this latter claim justified? Certainly not. It can only be said that Dale Gloria varies from 83.3 to 43.5 internodes per 100 mm. of rachis length and Amber Longberry from 33.3 to 18.5. One must bear in mind that a difference of 5 internodes between classes 15 and 20, for instance, is entirely different from the same difference between classes 85 and 90. While a difference of 5 internodes between classes 85 and 90 makes a difference of 0.07 mm. on the average internode length, the same difference of 5 internodes between classes 10–15 produces a difference of 1.66 mm., a figure 14.4 times greater.

Here one confronts another difficulty. What does this standard deviation of a distribution such as that of curve *A′* (fig. 13) show? Briefly, it shows hardly anything, because the standard deviation which is meant to show some form of departure above and below the mean can not be applied to a distribution where the density values of classes, as was shown above, are different. Referring to curve *A′* (fig. 13) the calculated standard deviation was found to be 8.093 internodes per 100 mm. rachis length. As 8.093 internodes below the mean have a density value several times greater than the value of the same number of internodes above the mean, our standard deviation thus calculated fails to express the type of deviation which the coefficient under consideration is expected to show.

It must not be concluded, however, from the above discussion that expression of density in terms of number of internodes per 100 mm. rachis length is itself absurd. On the contrary, it is mathematically correct, but it is misleading and does not lend itself easily to the application of statistical methods which are commonly in use.

What was said above for formula 3*b* applies also to formulæ 1*b*, 2*b*, and 4, because the principle upon which they work is essentially the same.

Two other formulæ were mentioned which did not express density on the percentage basis. They were formula 1*a*, where the density was found by dividing the number of spikelets into the total length of the head, and formula 2*a*, where the number of spikelets was divided

into the length of the rachis. It was already said at the beginning of this paper that density found with the first formula (1*a*) depended largely upon the length of the terminal spikelet, the error of which would increase with the shortness of the head. As to the second formula, it can neither be used in place of formula 3*a* nor preferred over it because the standard taken is not logical. There is no reason why density should be expressed by dividing the number of spikelets into the length of the rachis, because the rachis itself is not made of spikelets but of rachis internodes; furthermore, the number of spikelets does not correspond to the number of rachis internodes.

In conclusion it may be said that of all the formulæ given thus far the average internode length represents the best method for determining density, as density is dependent directly upon the length of the rachis and the number of its units, the internodes, of which it is composed.

## 2. The Coefficient of the Squarehead Forms.[3]

The average rachis internode-length which is the best index of density suggested has certain limits. It can not bring out the difference between a squarehead and a nonsquarehead. A comparison of types 2, 3, 4, 5, and 6 is sufficient to show this (Table 6).

Table 6.—*Comparison of internode lengths of several types of wheat.*

| Measurement. | Type number and species. | | | | |
|---|---|---|---|---|---|
| | 2. *T. vulgare.* | 3. *T. vulgare.* | 4. *T. capitatum.* | 5. *T. compactum.* | 6. *T. compacto-capitatum.* |
| Rachis length, mm. | 78 | 61 | 75 | 41 | 35 |
| No. of internodes | 19 | 17 | 19 | 18 | 19 |
| Av. internode length, mm. | 4.10 | 3.59 | 3.95 | 2.28 | 1.84 |

We know from the diagrams in fig. 14 that types 4 and 6 are squarehead forms, but this index of density fails to reveal it. For instance, the density of type 4, a typical squarehead, is 3.95; it is slightly below the internode length of type 2 and above that of type 3, both *vulgare* forms. There is no marked difference between the internode length of the squarehead and that of the *vulgare* forms.

The same inability of distinguishing the squarehead form from a nonsquarehead form is found when the density of the same squarehead (type 4) is compared with that of the *compactum* form (type

[3] A paper presented at the annual meeting of the American Genetic Association, Berkeley, Cal., August 5, 1915.

5). The difference between the squarehead and the other forms is not merely a matter of density. Therefore, the use of any formula showing mere density is of no value when the object is to bring out the character of squareheadedness.

The difference between this form and the *vulgare* form particularly is the compactness of the terminal portion of the spike, which is the direct result of the shortening of the internodes in that region. On account of this shortening, the terminal spikelets mechanically diverge (see diagram) in order to have more room for development. As the tip of the diverging spikelet is farther from the rachis than that of the spikelet lying close to the rachis (type 1), the width of the head in the region of shorter internodes is greater than that of the basal portion. This widening of the tip has suggested the name of "club." On account of the widening of the tip and some other factors which need not be mentioned in this paper, the head makes a twisting movement a day or two before and also during the period of heading; this twisting draws the terminal spikelets toward one side, exposing to view one side of the rachis. Where the spikelets are drawn away the surface appears somewhat flat, and when the head is viewed from this flat side it gives the impression that the head is square in cross-section, although in reality it is more or less triangular. On account of this popular belief heads showing this character are called "squareheads." Because of similar differences in internode length one of the species of barley is popularly called "four-rowed" as distinguished from the "six-rowed," although there is no such a thing as "four-rowed" barley, as a close examination will readily show.

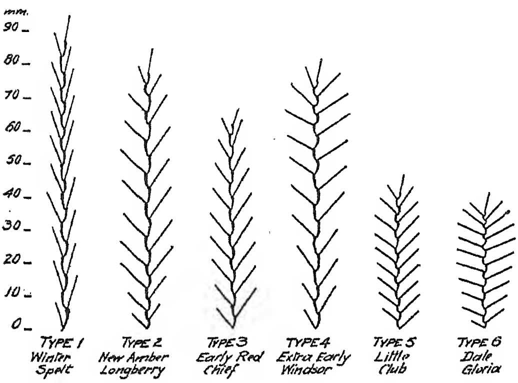



FIG. 14. Diagrams showing the arrangement of the spikelets on the rachis in several types of wheat.

Let it be pointed out also in this connection that squarehead and nonsquarehead forms exist among the denser types. Types 5 and 6 respectively show this difference. These two forms are now classified as *Triticum compactum,* distinguishing them from *T. capitatum,*

the squarehead. As the apparent difference and the genetic behavior between types 5 and 6 are as marked as those of types 2 and 4, a distinction needs to be made. For this reason it is suggested in this paper that *T. compactum* be used for compact wheats which lack squareheadedness and *T. compacto-capitatum* for compact, squareheaded forms. The fact that uniform and squarehead forms exist in dense as well as in lax types needs be considered in making classification of cultivated wheats.

Having discussed the differences between the squarehead and uniformly dense types, the question arises as to how to express this difference and all its gradations in terms of a coefficient which may be adopted in statistical work.

Since squareheadedness is the result of the shortening of the terminal internodes, a number of methods were tried to bring out this difference. It was found that the ratio between the number of internodes in the middle third of the rachis and the number of internodes in the upper third would best express the degree of squareheadedness. This coefficient of squareheadedness, represented by the symbol "$Sq$," is found by the formula

$$Sq = \frac{I_1}{I_2}$$

where $Sq$ = coefficient of squareheadedness;

$I_1$ = number of internodes in the terminal third of the rachis; and

$I_2$ = number of internodes in the middle third of the rachis.

This formula represents in reality the relative density of these two regions. This is elucidated in the following formula:

$$Sq = \frac{\frac{I_1}{\frac{R}{3}}}{\frac{I_2}{\frac{R}{3}}}; \qquad R = \text{length of rachis.}$$

Cancelling $R/3$ in both the numerator and the denominator the simplified formula already given is obtained. The results shown in Table 7 are obtained from the use of this formula.

The new coefficient, it is seen, has brought out very markedly the difference between the squareheads and other forms. It shows, for instance, in the case of type 3 that there is not much difference between the densities of the two regions in question, while in type 4 the terminal portion is 1.55 times denser than the middle third. It is also of special interest to notice that *T. compactum* (type 5),

although dense, was not affected at all. This would naturally be expected, for the rachis internodes of the latter are short but more or less uniform.

TABLE 7.—*Coefficients of squareheadedness in several types of wheat, as determined by the formula,* $Sq = \frac{I_1}{I_2}$.

| Measurement. | Type number and species. | | | | |
|---|---|---|---|---|---|
| | 2. *T. vulgare.* | 3. *T. vulgare.* | 4. *T. capitatum.* | 5. *T. compactum.* | 6. *T. compacto-capitatum.* |
| No. of internodes in upper third of rachis | 6.2 | 5.7 | 8.4 | 5.8 | 8.0 |
| No. of internodes in middle third of rachis | 5.6 | 5.3 | 5.2 | 5.6 | 5.1 |
| Coefficient of squareheadedness (Sq.) | 1.10 | 1.07 | 1.55 | 1.03 | 1.53 |

In describing a compact form the use of density as found in terms of average internode length should not be neglected altogether, for the new coefficient is meant to represent degrees of squareheadedness only. If a clear idea of the shape and length of the head is desired the density should accompany this coefficient. Thus, types 4 and 5 are represented as

Type 4 .......................... $Sq = 1.55$, $D = 3.95$,
Type 5 .......................... $Sq = 1.03$, $D = 2.28$.

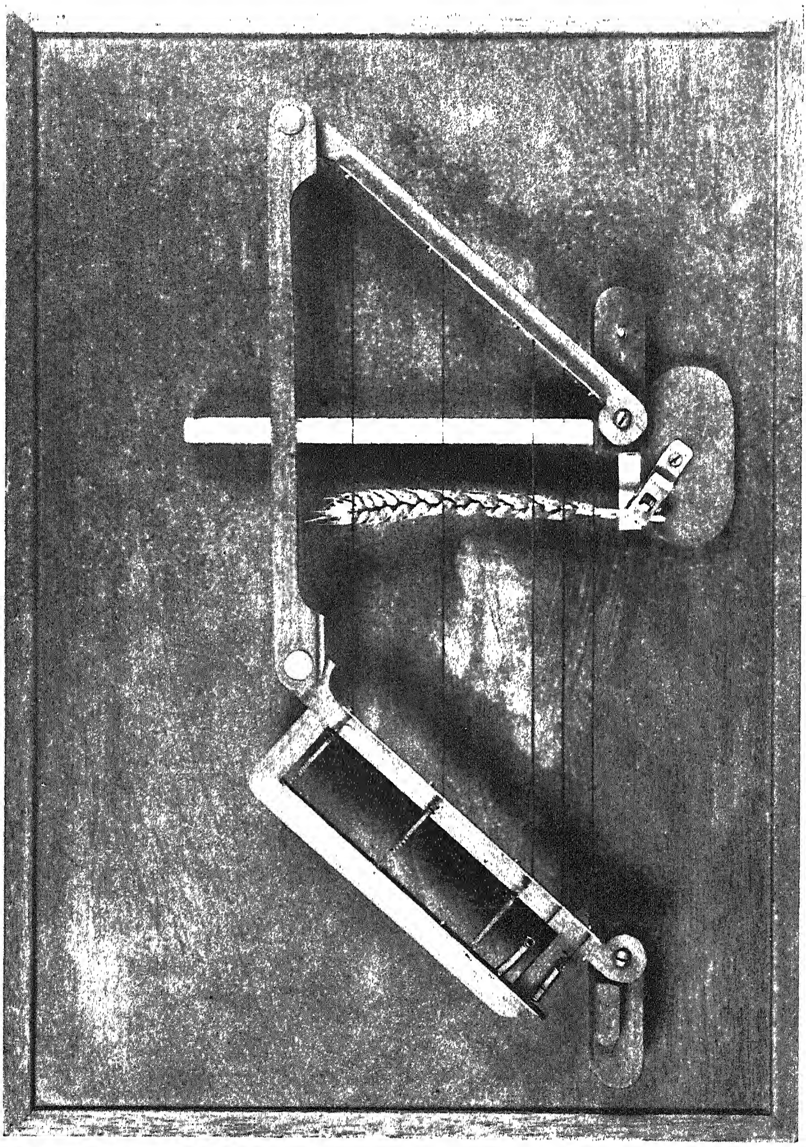
These figures show that type 4 is a long, open squarehead, and type 5 a short and dense wheat of uniform internode length.[4]

When the material to be measured is grown in the greenhouse or has certain abnormalities, such as sterile or rudimentary terminal internodes or abnormally long basal internodes, it will be found more satisfactory to express the density in terms of the average internode length of the middle third of the rachis. Where the head develops normally, there is no reason why the average internode length of the head should not be used.

### 3. THE INSTRUMENT FOR MEASURING SQUAREHEADEDNESS.

When the density or squarehead coefficient of a large number of heads is to be determined, the use of an instrument which will do the work rapidly and accurately becomes necessary. An instrument devised by the writer for this purpose is shown in Plate 7, and a

[4] Experience has shown that all gradations exist between the squarehead and *vulgare* forms, and the forms which by sight might be classified as squareheads have a coefficient almost always above 1.33.



Instrument for measuring squareheadedness. Constructed by the Office of Cereal Investigations, U. S. Department of Agriculture, after the author's plan.

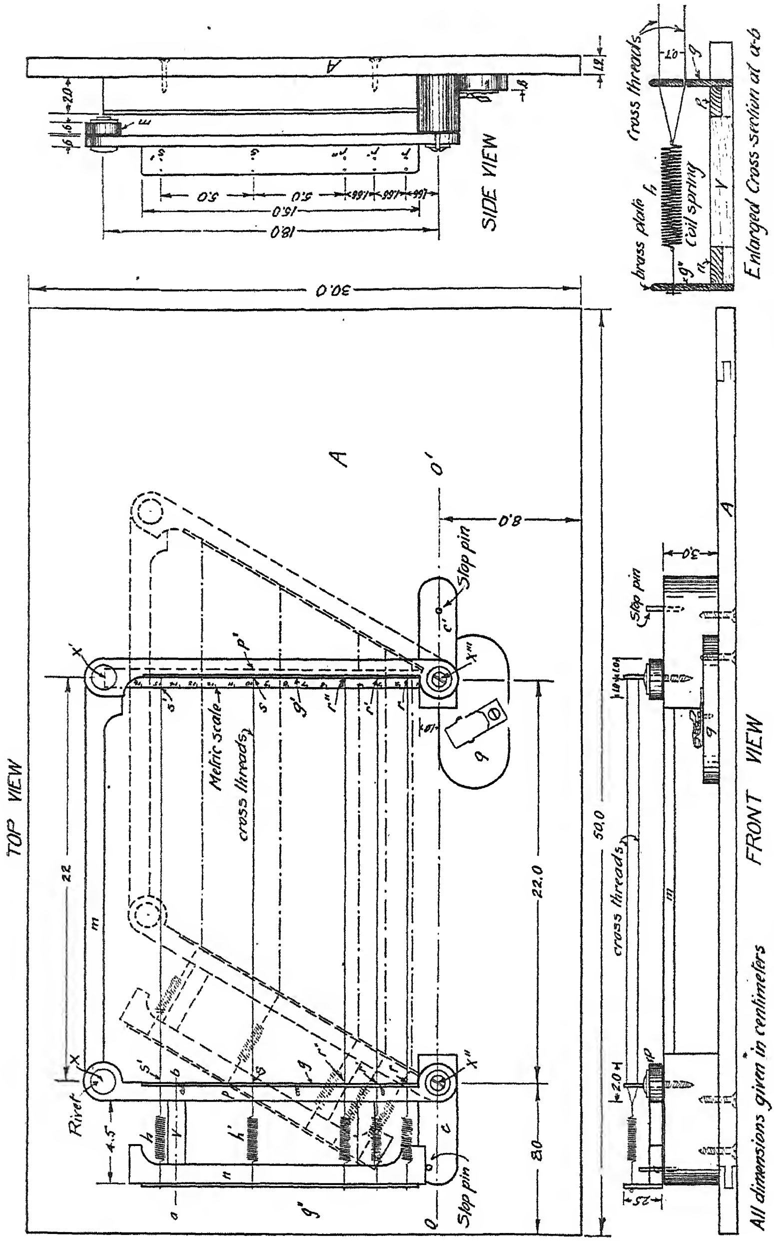



FIG. 15. Working plan of instrument used in measuring squareheadedness and density.

working plan, slightly modified, in figure 15. The instrument consists of a rectangular wooden base *A* (fig. 15, top view) over which by means of wooden blocks, *c* and *c'*, two arms equal in length, *p* and *p'*, are supported. The arms are held parallel to each other with a cross bar *m*, the distance between the centers of the rivets *x* and *x'* being *exactly* equal to the distance between centers at *x''* and *x'''* where the arms are pivoted. Along the sides of the arms which face each other, brass plates, *g* and *g'*, are fastened. These brass plates carry five pairs of holes large enough for a thread to pass through; three of these pairs, *r*, *r'* and *r''*, are spaced 1.66 cm. from each other, as shown in the drawing (side view), so that the last pair, *r''*, is 5 cm. from the stationary centers *x''* or *x'''*; the other two pairs, *s* and *s'*, are 5 cm. apart from each other. These pairs of holes are perpendicular to the long side of the plate and therefore parallel to each other. Through the corresponding holes on brass plates *g* and *g'* which face each other pass waxed silk threads each pair of which is held in tension by coil springs, *h*, *h'*, etc. The details of this arrangement are shown in the lower right-hand corner of figure 15.

The first set of threads, *s'–s'*, *s–s*, and *r''–r''*, divide the distance between the cross thread *s–s'* and the imaginary base line *O–O'* into three equal parts by parallel planes of vision which pass through each pair of threads. The distance between imaginary line *O–O'* and *r''–r''* is also divided into three equal parts by a second set of threads, *r'–r'*, and *r–r*. When the arms of an accurately constructed instrument are in normal position, as shown in full lines in the drawing, the threads *s'*, *s*, *r''*, *r'*, *r*, should register on the metric scale 15.00, 10.00, 5.00, 2.33, and 1.66 cm., respectively. By moving the arms towards the right to the position shown in dotted lines, for instance, the movable parts assume the form of a parallelogram. As the distance between *s'–s'* and *O–O'* decreases, the distance between each pair of threads decreases also in the same ratio; the threads of each set, therefore, remain always equidistant and parallel to each other. These are the principles upon which this instrument is constructed.

The manipulation of the instrument just described is extremely simple. If the length of the rachis is less than 5 cm. the lower set of threads (*r''–r'*, *r'–r'*, *r–r*) is used for dividing the head into three equal parts, otherwise the upper set (*s'–s'*, *s–s*, *r''–r''*) is used. The culm of the head to be measured is held firmly with a clasp provided for this purpose, and the base of the rachis brought in line with the imaginary line *O–O'* (fig. 15). In the drawing this line is represented by the upper edge of the block *q* and in the illustration (Plate

7) by a white object placed in the same position. Now the movable parts are swung so that cross thread $s'$–$s'$ is in line with the tip of the rachis (fig. 15). The spike is thus divided into three equal parts. As the formula for the squarehead form calls for the counts of the number of internodes in the upper and middle third of the rachis only, these data only need to be taken. In the case of the head in the illustration, the upper third contains 13 rachis internodes and the middle third 6.4; the coefficient of the squarehead form is therefore $13 \div 6.4 = 2.03$.

Such data are usually accompanied with the average internode length. Therefore the length of the rachis registered by the upper cross thread on the metric rule is also recorded and the count of the total internodes made later, or if the material is such that the average internode length does not give a satisfactory index of the compactness, as in the case of some deformities of the basal rachis internodes, then the third of the length of the head as registered by cross-thread $r''$–$r''$ is recorded. In this case it is not necessary to count internodes, as the count of the internodes at the middle third has already been recorded. According to the formula this latter figure is divided into the third of the length of the rachis and a figure is obtained which shows the average internode length of the middle third of the rachis.

This instrument, then, performs simultaneously three operations: (1) It divides the rachis into three equal parts, (2) it registers the length of the rachis, and (3) it registers the third of the length of the rachis.

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# THE MOISTURE CONTENT OF HEATING WHEAT.[1]

C. H. Bailey.

During the latter part of July and first half of August, 1916, an unusually large proportion of the wheat sampled by the Minnesota Grain Inspection Department was found to be in a heating condition. Several hundred cars of heating spring wheat were received at Minneapolis, in addition to large quantities of other cereals. The condition of this grain varied from incipient heating to a badly bin-burned or mahogany-colored character.

The weather from the middle of July to the middle of August, 1916, was characterized by unusually high temperatures. The mean of the maximum daily temperatures for July, 1916, at Minneapolis was 88.3° F., while the same record for July, 1915, was 75.5°. Similarly, the mean of the maximum daily temperatures for August, 1916, was 81.7° F., while the same month of the preceding year it was 75.0°. This hot weather induced heating in grain which would have remained sound under normal conditions. It is known that a high temperature accelerates respiration in grain, which respiration, if sufficiently rapid, results in the phenomenon known as heating, or bin-burning. If the enzymic changes known in the aggregate as respiration follow the usual rules with regard to the relative acceleration of enzyme activity resulting from an increase in temperature, an increase of from two and a half to three times in the rate of respiration should result from a rise of 18° F. (10° C.) in temperature. This would effect a corresponding increase in the amount of heat developed as the result of the biological combustion or oxidation which constitutes an important part of respiration. Moreover, a smaller proportion of the heat developed is radiated or conducted from heating grain into a surrounding hot atmosphere than into cool air. Accordingly, hot weather accelerates heating in grain in two ways, biochemically through the effect on the rate of enzyme action, and physically by reducing the rate of conduction of heat into the atmosphere.

Rumors became current in Minneapolis that "dry" wheat was heating as readily as the damp grain. In order to ascertain the accuracy of such statements and to determine the actual moisture content

[1] Contribution from the Minnesota Grain Inspection Department Laboratory. Received for publication January 27, 1917.

of heating grain, the writer personally examined and analyzed the samples drawn from a large number of cars. Mr. Albert Nelson was detailed to assist in the investigation and his painstaking, accurate work contributed materially to its progress.

For the purposes of our work it was found most convenient to visit the sidings of certain of the grain hospitals engaged in conditioning the hot wheat, in order to gain access to the largest possible number of cars each day. During the 14 days from August 3 to 16 about 70 cars of various types of heating wheat were examined in this manner, in addition to a number of lots of other grain.

These studies served to emphasize the necessity of placing the samples in tight containers as soon as drawn from the bulk. In hot weather a 3-pound sample in a cloth sack will lose several tenths of 1 percent of moisture while it is being transported from the yards to the office, and if left in the sack over night the loss of moisture may amount to several percent. A failure properly to prevent evaporation from this grain was probably the cause of the erroneous ideas concerning the moisture content of some of the heating wheat. All the samples taken in this work were placed immediately in 4-ounce glass bottles which were tightly stoppered. These were not opened until a portion was weighed into a covered aluminum drying capsule. The moisture was determined by drying the unground kernels in an air oven at a temperature of 98° C.

In tabulating the data the samples were arranged in order of their moisture content, and are grouped with a range of five-tenths of 1 percent of moisture in each group. Such information as was furnished by the railroad companies concerning the source of the grain and the date on which it was loaded into cars was incorporated in the table. In a few instances no such record could be obtained. No information concerning the previous history of the grain before it was loaded into the cars could be gotten. It is probable, however, that in many instances the grain was in a heating condition before it was shipped.

In discussing these data with members of the grain inspection service the question was raised as to how much moisture may have been lost by evaporation from the heating mass. Undoubtedly some loss had occurred in this manner from many of the lots examined. The amount of loss depends in large part upon the temperature which it had reached and the length of exposure. With the data available any estimate of the loss would be pure speculation, and no attempts were made in that direction. One thing appears evident, however; the moisture content of sound, plump spring wheat must be above

TABLE 1.—*Moisture content and other data relating to heating wheat sampled at Minneapolis, Minn., August 3–16, 1916.*

| Lab. No. | Moisture. | Dockage per bushel. | Weight per bushel. | Weight per 1,000 kernels. | Consigned from — | Date loaded. | Date sampled. | Days in the car. |
|---|---|---|---|---|---|---|---|---|
| | *Percent.* | *Lbs.* | *Lbs.* | *Grams.* | | | | |
| | | | | LESS THAN 14 PERCENT MOISTURE. | | | | |
| 119*a* | 13.50 | 2 | 57 | 26.64 | Langdon, N. Dak. | July 19 | Aug. 12 | 24 |
| 46*a* | 13.78 | 2½ | 55½ | 23.16 | Gibbon, Minn. | July 20 | Aug. 3 | 14 |
| | | | | 14.01 PERCENT TO 14.50 PERCENT MOISTURE. | | | | |
| 142*a* | 14.04 | 2 | 52 | 19.56 | Eureka, S. Dak. | July 28 | Aug. 14 | 17 |
| 85*a* | 14.11 | 3 | 53 | 24.76 | Pierpont, S. Dak. | July 29 | Aug. 8 | 10 |
| 94*a* | 14.19 | 4½ | — | 21.24 | Pioneer Steel Elevator | July 11 | Aug. 9 | 29 |
| 88*a* | 14.21 | 2½ | 54 | 21.60 | Tracy, Minn. | Aug. 1 | Aug. 8 | 7 |
| 84*a* | 14.27 | 1 | 50 | 17.16 | Victoria Elevator | July 29 | Aug. 8 | 10 |
| 43*a* | 14.34 | 2 | — | 27.76 | Perella, N. Dak. | | Aug. 3 | |
| 89*a* | 14.34 | 1½ | 55 | 27.96 | Brittin, N. Dak. | July 26 | Aug. 8 | 13 |
| 99*a* | 14.36 | 1½ | 59 | 27.48 | Dunn Center, N. Dak. | June 27 | Aug. 9 | 43 |
| 72*a* | 14.43 | 1 | 56 | 23.62 | Timmer, N. Dak. | July 20 | Aug. 7 | 18 |
| 143*a* | 14.43 | 2½ | 55 | 24.52 | Longwood, N. Dak. | Aug. 4 | Aug. 14 | 10 |
| 116*a* | 14.44 | 1½ | — | 32.80 | Mowbray, N. Dak. | Aug. 2 | Aug. 11 | 9 |
| 75*a* | 14.45 | 2½ | — | 24.20 | Killdeer, N. Dak. | July 26 | Aug. 7 | 12 |
| 115*a* | 14.49 | 1½ | 54 | 22.60 | Marfield Elevator | July 28 | Aug. 11 | 14 |
| | | | | 14.51 PERCENT TO 15.00 PERCENT MOISTURE. | | | | |
| 114*a* | 14.52 | 1½ | 56½ | 23.44 | Doland, S. Dak. | Aug. 2 | Aug. 11 | 9 |
| 73*a* | 14.56 | — | 55 | 24.62 | Calumet Elevator | July 21 | Aug 7 | 17 |
| 141*a* | 14.56 | — | — | 28.68 | No record | | Aug. 14 | |
| 96*a* | 14.60 | 1 | 54 | 29.52 | Demming, N. Dak. | Aug. 1 | Aug. 7 | 6 |
| 50*a* | 14.66 | 2½ | — | 17.58 | No record | | Aug. 3 | |
| 146*a* | 14.68 | 1½ | — | 27.56 | Marfield Elevator | July 29 | Aug. 15 | 17 |
| 49*a* | 14.70 | 1½ | 54 | 20.02 | Eureka, S. Dak. | July 17 | Aug. 3 | 17 |
| 123*a* | 14.77 | — | — | 25.16 | No record | | Aug. 12 | |
| 97*a* | 14.81 | ½ | 53½ | 23.00 | Dickinson Elevator | Aug. 2 | Aug. 9 | 7 |
| 118*a* | 14.83 | 3 | 55 | 20.96 | Wilton, N. Dak. | July 23 | Aug. 11 | 19 |
| 74*a* | 14.86 | ½ | 56 | 25.38 | Kansas City, Mo. | July 27 | Aug. 7 | 11 |
| 77*a* | 14.88 | — | — | 18.90 | Platte, S. Dak. | June 30 | Aug. 7 | 38 |
| 124*a* | 14.94 | ½ | 56 | 28.24 | Kempton, N. Dak. | Aug. 5 | Aug. 12 | 7 |
| 80*a* | 14.97 | ½ | 57 | 27.84 | Lawton, N. Dak. | July 31 | Aug. 7 | 7 |
| 44*a* | 14.98 | 2 | — | 25.72 | Talmo, N. Dak. | July 15 | Aug. 3 | 19 |
| 121*a* | 15.00 | 2 | 56½ | 24.64 | Bixby, Minn. | Aug. 8 | Aug. 12 | 4 |
| | | | | 15.01 PERCENT TO 15.50 PERCENT MOISTURE. | | | | |
| 92*a* | 15.02 | 1 | 55 | 28.52 | Wall, S. Dak. | Aug. 2 | Aug. 9 | 7 |
| 125*a* | 15.06 | 4 | 55 | 24.80 | Killdeer, N. Dak. | July 26 | Aug. 12 | 17 |
| 101*a* | 15.11 | 1 | 57 | 29.56 | Wales, N. Dak. | July 28 | Aug. 9 | 12 |
| 51*a* | 15.15 | 6½ | 47 | 14.52 | | | Aug. 3 | |
| 144*a* | 15.15 | 1 | 52½ | 22.44 | Glenville, Minn. | Aug. 8 | Aug. 15 | 7 |
| 71*a* | 15.18 | ½ | 58 | 30.12 | McHenry, N. Dak. | July 26 | Aug. 7 | 12 |
| 149*a* | 15.30 | 2½ | — | 26.08 | Phelps, N. Dak. | Aug. 3 | Aug. 16 | 13 |
| 106*a* | 15.34 | 1 | 59 | 28.72 | Marfield Elevator | July 26 | Aug. 10 | 15 |
| 79*a* | 15.40 | 3 | 56 | 26.74 | Lawton, N. Dak. | July 26 | Aug. 7 | 12 |

OVER 15.51 PERCENT MOISTURE.

| Lab. No. | Moisture. | Dockage per bushel. | Weight per bushel. | Weight per 1,000 kernels. | Consigned from— | Date loaded. | Date sampled. | Days in the car. |
|---|---|---|---|---|---|---|---|---|
| | *Percent.* | *Lbs.* | *Lbs.* | *Grams.* | | | | |
| 109*a* | 15.52 | ½ | 54 | 22.08 | Hazelton, N. Dak. | Aug. 1 | Aug. 10 | 9 |
| 110*a* | 15.54 | 1 | — | 30.36 | Gwinner, N. Dak. | Aug. 3 | Aug. 10 | 7 |
| 45*a* | 15.56 | 2½ | — | 19.24 | No record | | Aug. 3 | |
| 122*a* | 15.59 | ½ | 55 | 22.92 | Eureka, S. Dak. | Aug. 4 | Aug. 12 | 8 |
| 112*a* | 15.68 | — | — | 27.92 | | | Aug. 10 | |
| 147*a* | 15.66 | 3 | 52 | 20.88 | Ashley, N. Dak. | Aug. 10 | Aug. 16 | 6 |
| 93*a* | 15.70 | 5 | 56 | 30.28 | No record | | Aug. 7 | |
| 145*a* | 15.87 | ½ | — | 18.92 | Westfield, Iowa | Aug. 7 | Aug. 15 | 8 |
| 126*a* | 16.15 | 2½ | 56 | 25.84 | Coteau, N. Dak. | July 28 | Aug. 12 | 15 |

the normal (about 13.75 percent) before heating ensues, even under the extreme conditions of the hot summer weather of 1916, as there is no reason to believe that there was any material increase in the moisture content after the grain started to heat. Two samples were taken from heating wheat which contained less than 14 percent of moisture but neither of these were normal grain. Sample 119a was frosted, while 46a was shriveled. It will be observed that all the heating samples containing less than 14.3 percent of moisture were shriveled, with a low weight per bushel, indicating a greater tendency on the part of such grain to heat. Since all of the normally plump spring wheat that heated contained over 14.3 percent of moisture, and there is reason to believe that the moisture content before heating commenced was higher, the writer concludes that sound, plump, hard wheat containing less than 14.5 percent of moisture will keep without heating in storage in a temperate climate. A lower moisture limit must be employed in storing shriveled or frosted wheat, and possibly with sound, plump wheat in a tropical climate.

MINNESOTA GRAIN INSPECTION DEPT. LABORATORY,
MINNEAPOLIS, MINN.

# AGRONOMIC AFFAIRS.

## NEW BOOKS.

*Organic Agricultural Chemistry (The Chemistry of Plants and Animals)*. By Joseph Scudder Chamberlain, Professor of Agricultural Chemistry, Massachusetts Agricultural College. The Macmillan Co., New York, 1916. Pages xvii plus 319.

The subject matter of this book is divided into three sections entitled, respectively, Systematic, Physiological, and Crops, Foods and Feeding.

The first section includes what is the first satisfactory survey which is known to the reviewer of the general and fundamental principles of organic chemistry from the viewpoint of the student or instructor who desires to make use of the subject for the study of plant and animal life rather than for advanced study of organic compounds and relationships of scientific interest. The presentation, though necessarily brief and including only those types of carbon compounds which are involved in nutritional or physiological processes, is carefully worked out and is sufficient for most collegiate students of plant, animal, or human nutrition. The omission of any discussion of the closed-ring compounds is a sacrifice to brevity which will make necessary some supplemental instruction, if the physiological function of certain important units of the proteins is to be understood. The postponement of the discussion of the "unsaturated compounds" to the last pages of the section makes the consideration of the chemistry of the fats and of certain of the alcohols and mixed compounds rather inadequate, and an earlier consideration of these would improve the whole section. But these are only minor faults in what is otherwise a very satisfactory arrangement and choice of subject matter.

The second section deals, in successive chapters, with enzymes and enzymatic action; the living cell and its food; animal food and nutrition; milk, blood, and urine; and plant physiology. The departure from the usual custom, namely, the consideration of the nutrition of animals before the study of the biochemistry of plants, is considered by the author to emphasize "the real difference between these two forms while retaining the idea of fundamental similarity." The re-

viewer prefers the customary arrangement of studying first the synthesis of organic matter from its elements by plants, followed by the more complex syntheses and reactions which constitute animal metabolism, but recognizes as a commendable feature of the innovation that the unity rather than the dissimilarity of these two phases of biochemistry is emphasized. The subject matter of this section, though brief and simply presented, is admirably selected and will prove an excellent preparation for further studies of practical nutritional problems.

Section III contains two chapters dealing with the occurrence and uses of important constituents in agricultural plants, in which the composition of the more common carbohydrates, fats, lipoids, and proteins, and their industrial and nutritional uses are briefly discussed. A third and final chapter contains a very brief but carefully prepared discussion of the quantitative relations of food consumption to energy production in the animal body. The subject matter of the entire section carefully avoids controversial discussions and presents in an admirable way a clear and satisfactory survey of the biochemical principles involved.

The book contains a few typographical errors, which will undoubtedly be corrected in later editions, but is commendably free from misstatements or confusing personal idiosyncrasies of expression or form. It is bound uniformly with the familiar Macmillan series, and the absence of illustrations has permitted it to be printed on the desirable rough surface book paper. The reviewer predicts a very general use of the book as a textbook for college students who are preparing for further study of animal or human nutrition, and regards it as a thoroughly satisfactory text for that phase of agricultural chemistry which may be designated as "biochemistry" to distinguish it from the study of soils and fertilizers, which is now commonly taught as a separate subject and from an entirely different viewpoint.—R. W. THATCHER.

## NO SUMMER ISSUES OF THE JOURNAL.

As announced earlier in the year, the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY will not be published during June, July, and August. The next issue will appear about September 15. While monthly issuance is desirable, our present income does not justify it. Those who feel that the publication of twelve numbers during the year is desirable can help in making such publication possible by obtaining new members for the Society. We need 100 more members this year.

## MEMBERSHIP CHANGES.

The membership of the Society, as reported in the April issue, was 663. Since that time 13 new members have been added and one has been reinstated. In the same period 4 members have resigned, 1 has died, and 29 have lapsed for nonpayment of dues for 1916. The net loss in membership is 20, making a total membership at this time of 643. The names and addresses of the new and reinstated members, with the names of those who have resigned and lapsed and of the deceased member, with such changes of address as have come to the notice of the Secretary, are as follows:

### New Members.

Booth, V. J., 318 West Street, Stillwater, Okla.
Darst, W. H., Dept. of Agronomy, State College, Pa.
Dickson, R. E., Substation No. 7, Spur, Texas.
Freeman, Ray, Box 255, Fort Worth, Tex.
Hill, C. Edwin, Eastern Oregon Dry-Farming Substation, Moro, Oreg.
Hill, Pope R., Box 625, Athens, Ga.
Milton, R. H., Clarksville, Tenn.
Robinson, R. B., Box 272, Stillwater, Okla.
Taggart, J. G., School of Agriculture, Olds, Alta., Canada.
Torgerson, E. F., 654 Agricultural Bldg., University of Illinois, Urbana, Ill.
Trout, C. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Van Evera, R., 16 Mendota Court, Madison, Wis.
Van Nuis, C. S., College Farm, New Brunswick, N. J.

### Members Reinstated.

Starr, S. H., College of Agriculture, Athens, Ga.

### Members Resigned.

Hendrick, H. B.,
Morse, Fred W.,
Scales, Freeman M.
Peacock, Walter M.,

### Members Lapsed.

Bassett, L. B.,
Benton, T. H.,
Brown, C. B.,
Cassel, Chas. E.,
Chapman, Jas. E.,
Clothier, R. W.,
Currey, Hiram M.,
Damon, S. C.,
Gilbert, Arthur W.,
Hershberger, Jos. P., jr.,
Holland, Robt. E.,
Hughes, H. D.,
Khankhoje, P. S.,
Kinney, H. B.,
Lechner, H. J.,
Lumbrick, Arthur,
McNeely, L. R.,
Newton, Robert,
Piper, Geo. E.,
Powers, W. L.,
Reid, Harold W.,
Rudolph, E. G.,
Scudder, H. D.,
Shiffler, C. W.,
Spafford, R. R.,
Taff, P. C.,
Tucker, Geo. M.,
Wilson, Bruce S.,
Worrall, Lloyd.

Member Deceased.

Young, Yungyen.

Addresses Changed.

Abbott, John B., R. F. D., Bellows Falls, Vt.
Allyn, Orr M., Fergus, Mont.
Beaumont, A. B., Dept. of Agronomy, Mass. Agr. College, Amherst, Mass.
Bell, N. Eric, Ashville, Ala.
Briggs, Glen, U. S. Agr. Expt. Sta., Agana, Guam.
Bushey, A. L., 210 Waldron St., La Fayette, Ind.
Conrey, G. W., Soils Dept., Ohio State University, Columbus, Ohio.
Finnell, Howard H., Box 118, Hartshorne, Okla.
Foord, Jas. A., 3 The Circle, Ithaca, N. Y.
Longman, O. S., Deloraine, Manitoba, Can.
Lyness, W. E., Cheyenne Field Station, Archer, Wyo.
Miles, F. C., Union Grove, Wis.
Moomaw, Leroy, Havre, Mont.
Morison, A. T., Connersville, Ind.
Osenburg, Albert, Scottsbluff Expt. Farm, Mitchell, Nebr.
Palmer, H. Wayne, 175 12th Ave., Columbus, Ohio.
Welch, J. S., L. D. S. Maori Agr. College, Hastings, N. Z.
Zerban, F. W., German Kali Works, Propaganda Dept., 42 Broadway, New York, N. Y.

## NOTES AND NEWS.

John L. Bayles, assistant in agronomy at the Garden City (Kans.) substation, has resigned to accept a position in the agricultural department of the St. Louis and San Francisco Railroad Company.

M. A. Brannon has resigned as president of the University of Idaho.

Glen Briggs of the Oklahoma college has been appointed agronomist of the United States experiment station on the Island of Guam.

I. D. Cardiff has resigned as director of the Washington station. His successor has not yet been named.

W. H. Johnson, assistant in the soils section at the Iowa station, is pursuing graduate studies at the University of Wisconsin. His work at the Iowa station is being conducted by Knute Espe.

Frank C. Miles, assistant in fiber crops in the U. S. Department of Agriculture, has resigned to engage in commercial work in fiber production at Union Grove, Wis.

A. T. Morison, assistant in crop production at the University of Illinois, since April 15 has been county agent in Fayette County, Indiana.

J. A. Ratcliff has resigned as assistant professor of experimental agronomy in the University of Nebraska, effective April 1, to engage in farming in Oklahoma.

The Secretary of Agriculture has appointed a Committee on Seed Stocks, of which R. A. Oakley is chairman. This committee hopes to act as a clearing house for seed supplies, particularly State shortages and surpluses. Agronomists who know of surplus stocks of seed which are not needed locally but which are likely to be useful elsewhere will confer a favor on the Committee by sending definite information to Mr. Oakley regarding them. This information will then be transmitted to those who report shortages. The Committee does not intend to interfere with State activities looking toward the equitable distribution of seed supplies, but hopes to aid the State organizations in locating stocks and in making these available where they are most needed.

# JOURNAL

OF THE

# American Society of Agronomy

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## A NEW WHEAT FOR KANSAS.


W. M. JARDINE.


### INTRODUCTION.

Attempts to improve farm crops by selection and breeding so often prove disappointing that the discovery or production of a really superior strain is always welcomed. Frequently a strain which promises well the first few years fails to sustain its record in later years, and conversely, many which show little promise in the beginning give good results later. In other words, while it is comparatively easy to isolate strains which are superior to the best varieties in certain points, it is very seldom that one is found which proves superior in all essential respects and which, therefore, under a wide variety of conditions, produces better yields or better quality of grain, or both.

Moreover, it is not easy to prove the superiority of a strain which fluctuates widely in yield or quality from year to year with respect to other varieties. If it yields better than other varieties in some seasons, it is not safe to say that it is the best variety, even though the average for several years is significantly higher, since the comparative value will depend on the frequency of those seasons to which it is especially adapted and this cannot be determined without testing for a longer period of time than is usually done.

A new wheat recently distributed in a limited way by the Kansas station has been giving such consistently good results in comparison with the standard varieties generally grown throughout the State that a brief statement of its yields and milling value, its history, and the


[1] Contribution from the Kansas Agricultural Experiment Station. Received for publication February 24, 1917.

methods by which it was obtained may prove of interest and value to others engaged in similar lines of work.

### Origin and History.

The new wheat, which has been named Kanred,[2] is the product of a single head selected in 1906 from Crimean (No. 1435 of the Office of Cereal Investigations, United States Department of Agriculture) by the Department of Botany of the Kansas State Agricultural College. In the fall of 1906, 554 head selections were sown and the following season 451 were harvested. These and 79 additional selections were sown in the fall of 1907, each strain in a single row with alternate check rows of Kharkof. Five hundred and thirty-three selections were harvested in 1908; 122 of these were selected for increase. Ten rows of each were sown in the fall of 1908, each row alternating with Kharkof as in the preceding season. Eighty-nine of these selections were harvested, sown in nursery rows as before, and turned over to the agronomy department with about 100 other strains in June, 1910, for further trial.

From 1911 to 1916, inclusive, several of the most promising selections, including Kanred, were grown in field plots on the agronomy farm. Single plots were grown in 1911 and 1912. Beginning with

[2] Kanred wheat is a product of the Kansas Agricultural Experiment Station and can not be credited to any single individual. It was selected by Professor H. F. Roberts of the botany department in June, 1906, with over 500 others and was grown by him in nursery rows in 1907, 1908, and 1909. It was transferred to the agronomy department in 1910 with nearly 200 other strains, 89 of which were thought to be of superior merit, for further trial and has been grown by that department and its farmer cooperators until the present time.

The author in the capacity of agronomist took charge of the cereal crop improvement work in June, 1910, when the present work except as noted above was started. First as agronomist and later as director of the station it has been his special care to keep the various phases of the work correlated and allow none of them to lapse because of neglect or changes in personnel.

Credit is due to Professor L. E. Call, who, as agronomist, has supported the work in a most commendable way; to Prof. S. C. Salmon, who has had charge of the cereal improvement work since 1913; to Mr. H. H. Laude, who had charge of the details of the cereal improvement work in 1911 and 1912; and to Mr. R. K. Bonnett and Mr. R. P. Bledsoe in the same capacity in 1913 and in 1914 and 1915 respectively.

Special mention is due Mr. C. C. Cunningham and Mr. Bruce Wilson for efficient and careful work in conducting the cooperative tests with farmers; and to Professor L. A. Fitz and Miss Leila Dunton for conducting the milling and baking tests and chemical analysis of the wheat and flour.

Credit for assistance in the preparation of this manuscript and assembling the data used is due to Prof. S. C. Salmon.

1913, three fortieth-acre plots of each variety have been grown, the plots being distributed over the area used for the test to reduce the experimental error. Since 1914 the Kanred has been grown on the substation at Hays, Kans., and in cooperative tests with farmers throughout the hard winter wheat belt. It has been grown at the substations at Colby and Garden City, Kans., since 1915. Milling and baking tests and chemical analyses of the most promising strains at Manhattan have been made each year since 1912.

### Characteristics.

The wheat in question is a hard winter variety, characterized by the presence of awns, whitish, glabrous glumes, and reddish grain of the well-known Crimean or Turkey type. In habit of growth and general appearance the plant and grain cannot be distinguished from Turkey and Kharkof unless it be in minute botanical differences which have not been determined. It usually heads and ripens somewhat earlier than Turkey and Kharkof, but this difference is not sufficiently constant for identification.

### Yield.

The early records secured by the Department of Botany indicated the superiority of Kanred as compared with the varieties usually grown. However, it was not until it had been grown in field plots for six years and in cooperative tests with farmers in many parts of the State that its value was felt to be fully demonstrated. In both seasons in which it was grown in nursery rows it yielded considerably better than the adjoining check rows, although less than other selections grown with it. In 1908 it produced 29.5 percent and in 1909 over 30 percent more grain than the check rows of Kharkof. The difference has been somewhat less when grown in field plots. The yields and other agronomic data secured in the tests on the agronomy farm with Kanred, Turkey, and Kharkof are shown in Table 1. The Turkey and Kharkof strains are those which have been grown by the college for many years and have been widely distributed to farmers throughout the State.

It will be seen that the average yield of Kanred is 4.6 bushels higher than that of Turkey and 5.2 bushels higher than that of Kharkof. It has exceeded these varieties in yield in every year but one, and in that year the difference was less than the experimental error. In nearly every season the new variety has headed and ripened earlier than the other varieties mentioned. The average difference is from one to over two days. The average weight per bushel of Kanred

is 0.3 pound less than that of Turkey, and 0.9 pound higher than that of Kharkof. The difference is probably within the error of determination.

The probable error of the yield in each case where more than a single plot was grown has been computed and is included in the table, but great weight should not be given a probable error determined from three plots only as is the case here. Considering the large differences in favor of Kanred in 1912 and again in 1916, and the very great chances against a variety producing better than two others of like yielding ability in five years out of six, there can be little doubt as to the superiority of Kanred for this period and for the conditions under which it was grown.

TABLE 1.—*Yield and other agronomic data recorded on Kanred, Turkey, and Kharkof at Manhattan, Kans., in the six years from 1911 to 1916, inclusive.*

| Variety. | 1911. | 1912. | 1913. | 1914. | 1915. | 1916. | Average. | Difference compared with Kanred. |
|---|---|---|---|---|---|---|---|---|
| YIELD IN BUSHELS PER ACRE. | | | | | | | | |
| Kanred .. | 34.6 | 19.8 | 37.1±1.14 | 35.2± .96 | 26.0±.04 | 33.6± .28 | 31.1 | |
| Turkey .. | 31.1 | 13.2 | 33.6±1.59 | 36.1±1.09 | 23.0±.05 | 22.2±1.39 | 26.5 | −4.6 |
| Kharkof.. | 26.1 | 11.9 | 33.8± .63 | 36.0± .71 | 22.9±.05 | 24.6±1.78 | 25.9 | −5.2 |
| DATE HEADED. | | | | | | | | |
| Kanred .. | May 21 | | May 17 | May 22 | May 24 | May 25 | May 21.8 | |
| Turkey .. | do | | May 18 | May 24 | May 25 | May 26 | May 22.8 | 1.0 |
| Kharkof.. | do | | May 19 | May 25 | do | do | May 23.1 | 1.3 |
| DATE RIPE. | | | | | | | | |
| Kanred .. | June 7 | | June 17 | June 15 | June 30 | June 27 | June 19 | |
| Turkey .. | June 8 | | June 18 | June 17 | July 2 | June 29 | June 20.8 | 1.8 |
| Kharkof.. | do | | do | do | July 3 | June 30 | June 21.2 | 2.2 |
| WEIGHT PER BUSHEL, POUNDS. | | | | | | | | |
| Kanred .. | 60.5 | 62.5 | 57.0 | 59.0 | 57.0 | 59.3 | 59.2 | |
| Turkey .. | 62.0 | 60.5 | 57.9 | 59.6 | 55.0 | 60.2 | 59.5 | .3 |
| Kharkof.. | 61.8 | 57.3 | 59.3 | 58.4 | 54.0 | 59.0 | 58.3 | − .9 |

Very similar results were obtained in tests at the substations. The yields for Kanred at the substations, compared with Turkey or Kharkof, or both, are shown in Table 2.

No yield record was obtained at Hays in 1915, as extremely wet weather caused the grain to lodge so badly that accurate data could not be gotten. In each case the best strains of Turkey and Kharkof

grown at each station are included for comparison. In every test and in every year but one, Kanred outyielded Turkey and Kharkof. The average difference at Hays is 3 bushels, at Colby 2.8 bushels, and at Garden City 1.7 bushels. At Garden City in 1915 Kharkof and Kanred produced practically the same yield.

TABLE 2.—*Annual and average yields in bushels per acre of Kanred, Turkey, and Kharkof wheats at three substations in Kansas, 1914 to 1916.*

| Station and variety. | Yield in bushels per acre. | | | |
|---|---|---|---|---|
| | 1914. | 1915. | 1916. | Average. |
| Hays, Kansas: | | | | |
| Kanred | 25.6 | | 36.4 | 31.0 |
| Turkey | 23.3 | | 32.7 | 28.0 |
| Garden City, Kansas: | | | | |
| Kanred | | [a]15.4 | 17.2 | 16.3 |
| Turkey | | 13.8 | 15.3 | 14.6 |
| Kharkof | | 15.5 | 13.3 | 14.4 |
| Colby, Kansas: | | | | |
| Kanred | | 34.3 | 42.6 | 38.5 |
| Turkey | | 33.8 | 28.8 | 31.3 |

[a] Average of three tests.

Kanred was included in ten tests with farmers in the hard winter wheat belt in 1914, in 25 tests in 1915, and in 21 tests in 1916. In most cases Turkey and Kharkof from the college were included and also the variety used for seeding the general fields of the farmer conducting the test. In all cases this local variety was a hard winter wheat of the Crimean type and in many cases was the product of seed originally obtained from the college. These tests were conducted by seeding a plot one or two drill widths wide and of convenient length. The yields were determined by the hoop method to be described later. On account of the considerable space required the tabulated data showing the results in detail are omitted here.

In 1914 Kanred produced a higher yield than the local variety in nine tests of the ten that were conducted, and in the tenth, the difference was less than a quarter bushel. It also exceeded Turkey and Kharkof in every test but one and in this the difference was small. The average for all tests in 1914 show a gain of 3.4 bushels as compared with the local variety, of 2.5 bushels compared with Turkey, and of 3.2 bushels as compared with Kharkof.

In 1915 Kanred produced a higher yield than the local variety in 19 of the 23 tests which included both; higher than Turkey in 18 of 23 tests; and higher than Kharkof in 19 out of 24 tests. The average of those tests which included all four varieties shows a gain of 3.5

bushels compared with the local variety, 2.0 bushels compared with Turkey, and 4.5 bushels compared with Kharkof. The results for 1915 are somewhat more erratic than in 1914, due perhaps to the excessively wet season and considerable damage from disease and lodging.

There was but one test in 1916 in which a distinctly larger yield was secured from the local variety than from Kanred. In two tests practically the same yields were secured from each, while in 18 of the 21 tests conducted Kanred produced decidedly the most grain. Kanred gave higher yields than Turkey in all tests but two and in one of these the difference was well within the limits of experimental error. It produced higher yields than Kharkof in every test but one. The average gain was 6.2 bushels compared with the local variety, 5.9 bushels compared with Turkey, and 6.5 bushels compared with Kharkof. The superiority of Kanred was especially apparent in the north central and northeastern counties, where considerable winter injury to other varieties occurred.

To summarize, Kanred has given an average gain compared with Turkey of 4.6 bushels at Manhattan, 3.4 bushels in all tests at the substations, and 3.6 bushels in cooperative tests with farmers, or an average difference for all tests of 3.7 bushels. It has exceeded Kharkof by 5.2 bushels at Manhattan, 5.1 bushels in cooperative tests with farmers, and an average of 4.7 bushels for all tests. In the 54 cooperative tests with farmers which included the local variety; it gave an average increase of 4.4 bushels over the local strain. In all tests conducted it has exceeded Turkey in yield 59 times out of a possible 66, Kharkof 51 times out of a possible 58, and the local variety grown in cooperative tests 49 times out of 54.

## Earliness and Cold Resistance.

Kanred has headed and ripened on the average fully a day earlier than Turkey and more than a day earlier than Kharkof at Manhattan. It was observed in some of the cooperative tests that this strain was among the earliest to mature. In other cases it ripened at the same time.

There are strong indications that Kanred is able to survive severe winters better than other varieties. In 1912, which was the only season in which winterkilling occurred at Manhattan, notes taken in the spring show that 90 percent of Kanred plants survived as compared with 80 percent of Turkey and 77 percent of Kharkof. In the spring of 1916, Kanred was noticeably more vigorous in appearance

than other varieties. No severe winter injury occurred at Manhattan, but in the north central and northeastern parts of the State considerable injury occurred as a result of a heavy covering of ice during a part of the winter. In cooperative tests in this area, Kanred survived very much better than other varieties. This ice sheet was also present at Manhattan and may have been responsible for the large difference in yield between Kanred and other varieties, even though no immediate effect on the plants was noticeable.

It seems probable from experiments conducted at this station that winter injury may be due to several factors and that a variety resistant to one factor is not necessarily resistant to another. Hence, it would not be safe to infer that Kanred will prove hardier than other varieties with different conditions.

### Milling and Baking Tests.

Milling and baking tests of Kanred have been made since 1912. Table 3 presents the most important data in comparison with similar figures for Kharkof and Turkey in 1912, 1913, 1914, and 1915. The results for 1916 were not available when this paper was written.

Table 3.—*Data recorded on milling tests of wheat and baking tests of flour from Kanred, Kharkof, and Turkey wheats at Manhattan in 1912, 1913, 1914, and 1915.*

| Year and variety. | Wheat. | | Yield of flour. | Flour. | | Absorption. | Maximum expansion. | Oven rise. | Loaf volume. | Color. | Texture. | Weight. | Wet gluten. | Dry gluten. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Protein content. | Moisture content. | | Protein content. | Moisture content. | | | | | | | | | |
| | % | % | % | % | % | % | cc. | cm. | cc. | % | % | gm. | % | % |
| 1912: | | | | | | | | | | | | | | |
| Kanred..... | 17.40 | 9.89 | 67.08 | 17.02 | 11.34 | 58.3 | 2400 | 6.0 | 1940 | 94 | 93 | 518 | 57.66 | 16.43 |
| Kharkof..... | 17.38 | 10.84 | 65.40 | 16.90 | 11.67 | 60.0 | 2350 | 6.0 | 1900 | 96 | 97 | 523 | 57.93 | 16.60 |
| 1913: | | | | | | | | | | | | | | |
| Kanred..... | 17.02 | 8.32 | 65.68 | 15.15 | 12.77 | 61.7 | 2100 | 5.1 | 1910 | 93 | 96 | 531 | 49.38 | 14.89 |
| Kharkof..... | 11.38 | 10.84 | 65.04 | 9.34 | 13.92 | 62.7 | 2250 | 3.3 | 1760 | 92 | 95 | 532 | 29.02 | 9.12 |
| Turkey..... | 13.96 | 8.38 | 66.88 | 12.43 | 12.52 | 65.0 | 2100 | 4.3 | 1880 | 91 | 94 | 534 | 37.17 | 11.93 |
| 1914: | | | | | | | | | | | | | | |
| Kanred..... | 15.15 | 12.19 | 64.68 | 14.38 | 13.75 | 58.5 | 1900 | 4.7 | 1860 | 91 | 90 | 524 | 44.73 | 14.52 |
| Kharkof..... | 15.75 | 12.07 | 63.80 | 14.57 | 13.39 | 60.3 | 1800 | 4.2 | 1820 | 89 | 89 | 538 | 46.09 | 14.31 |
| Turkey...... | 14.37 | 11.36 | 65.16 | 13.04 | 13.43 | 59.4 | 1600 | 4.0 | 1800 | 87 | 89 | 525 | 38.13 | 12.11 |
| 1915: | | | | | | | | | | | | | | |
| Kanred..... | 20.78 | 13.02 | 59.10 | 18.22 | 13.94 | 60.0 | 2200 | 6.5 | 2040 | 93 | 94 | 513 | 58.41 | 17.58 |
| Kharkof..... | 18.85 | 12.78 | 58.80 | 16.48 | 13.73 | 60.0 | 2350 | 6.1 | 2030 | 93 | 91 | 521 | 50.56 | 15.90 |
| Turkey...... | 20.00 | 12.34 | 61.30 | 17.58 | 13.24 | 60.9 | 2350 | 6.6 | 2095 | 90 | 94 | 500 | 51.58 | 16.17 |
| Ave. 1912–15: | | | | | | | | | | | | | | |
| Kanred..... | 17.59 | 10.85 | 64.13 | 16.19 | 12.95 | 59.6 | 2150 | 5.6 | 1937 | 92.7 | 93.2 | 521 | 52.54 | 15.85 |
| Kharkof..... | 15.84 | 11.63 | 63.26 | 14.32 | 13.18 | 60.7 | 2162 | 4.9 | 1877 | 92.5 | 93.0 | 529 | 45.90 | 13.98 |
| Ave. 1913–15: | | | | | | | | | | | | | | |
| Kanred..... | 17.65 | 11.17 | 63.19 | 15.92 | 13.49 | 60.1 | 2067 | 5.4 | 1937 | 92.6 | 93.3 | 523 | 50.84 | 13.66 |
| Kharkof..... | 15.33 | 11.89 | 62.54 | 13.46 | 13.68 | 61.0 | 2133 | 4.5 | 1870 | 91.3 | 91.6 | 530 | 41.89 | 13.11 |
| Turkey...... | 16.11 | 10.69 | 64.45 | 14.35 | 13.06 | 61.7 | 2017 | 4.9 | 1925 | 89.3 | 92.6 | 520 | 42.26 | 13.40 |

Table 3 shows a distinctly higher protein content both in the wheat and in the flour of Kanred than of Turkey and Kharkof; a higher percentage of flour than Kharkof, but somewhat less than Turkey; a loaf expansion practically equal to Kharkof and slightly greater than Turkey; color of loaf equal to or better than either of the standard varieties; and texture of loaf equal or superior to either of the other varieties. The amount of dry and wet gluten is also distinctly in favor of the new variety. Stated in other words, there is no important point in which Kanred is shown to be inferior to the standards used and in some points, notably in protein and gluten content, it appears to stand distinctly higher. There would seem to be no question regarding its milling and baking value.

### Crop Improvement Methods.

It is difficult if not impossible to emphasize any one phase of the methods used that is responsible for Kanred. It is a product of the pure-line method of selection first used at this station by the Department of Botany. This method permits testing a much larger number of varieties and strains than was possible with the older method of continuous selection, and this without doubt has contributed largely to whatever success has been attained. Another point of considerable importance is the reduction of experimental error to the greatest extent possible by replication of plots and use of check plots and by exercising all possible care in the use and management of the land devoted to experimental work, in laying out plots, and in seeding, harvesting, and thrashing.

Land used for field plot work is handled in a definite rotation of (1) wheat, (2) corn, and (3) oats. Cowpeas are sown after the wheat as a catch crop and plowed under the following fall or spring for corn. No manure or commercial fertilizer has been used. The area used for the wheat plots is cropped uniformly to corn and oats the preceding two years, all experimental plots of corn and oats being on a different area. The nursery wheat plantings are alternated with a crop of oats and Canada field peas cut for hay. In all cases the ground is plowed early and thoroughly prepared before seeding. Seeding is delayed until danger from Hessian fly is practically past, but early enough to secure a good growth before winter.

In recent years nursery plantings have been replicated four times and field plots three times. Previous to this frequent checks were used. The outer drill rows of field plots have been removed before harvest to eliminate the alley effect. No provision has been made in nursery plantings to prevent the possible effect of adjacent rows, but

in recent years this effect has been reduced to a minimum by grouping all varieties and strains and growing those of like habits of growth together. In case of severe winter injury or other damage which is likely to affect adjacent rows, the possible effect is considered in interpreting the results. The heads of grain of all nursery rows are wrapped in paper to prevent loss and mixture, and thrashed in a specially constructed machine for the same purpose. The grain is reweighed to prevent possible mistakes.

### Farmers' Cooperative Tests.

A factor probably more important than any yet mentioned is the practice first developed at this station of thoroughly testing supposedly better strains with the farmers themselves before any wide distribution of seed is made. To the writer this seems of first importance, as the most accurate tests conducted at one place in a State with the diversity of soil and climate possessed by Kansas may mean nothing for other localities. Tests at the experiment station indicate something of the value of varieties for other localities, but they cannot prove their worth and it is a mistake to assume that they do.

This idea is not a new one in plant-breeding work, but it has never been emphasized as much as others of probably less importance. For example, in the German method of breeding, the principal method in vogue until less than 15 years ago, the main emphasis was placed on the selection of the best individuals each year for the propagation of an elite strain the following year. It was assumed that the improved varieties produced in this way would yield better than the unselected varieties, but very little effort was made to demonstrate the truth of this assumption. In the pure-line method which has practically supplanted the German method in this country, more attention has been given to determining the worth of the different selected strains, but in this method the necessity of testing the improved strains for all conditions to which they are supposed to be adapted has not been emphasized.

In Kansas improved varieties are sometimes sent into localities in which no formal test has been made, but only with the distinct understanding that they are sent for trial only and not with the unqualified recommendation of the experiment station.

### Methods of Conducting Cooperative Tests.

The method used in making tests in cooperation with farmers is important and may be of interest. In the first place, only those farmers who are willing and able to give some extra time to conduct-

ing the test are chosen. To these are sent about 15 pounds of each variety to be tested. Each test includes from four to ten varieties, one of them being the variety used by the farmer for general seeding. The remaining varieties include only those known in a general way to be adapted to the region. At seeding time a single drill-width or two drill-widths of each variety are sown, the length of the plot conforming either to the size of the field, the area of uniform soil available, or to the quantity of seed. The varieties are sown side by side with alleys 12 to 18 inches wide between plots. At harvest time a representative of the college visits the cooperator, takes such data as can be obtained at that time, and harvests a representative area of the plot for yield. The tests are inspected at other times of the year also as far as practicable. The yield is determined by harvesting from each plot ten areas inclosed by a hoop approximately 42 inches in diameter or a total area of 0.05 acre. The grain and straw when harvested are placed in a large jute sack with a tag inside and one outside and are then shipped by express to the college, where the grain is dried and later thrashed in the nursery thrasher.

Considerable care and judgment in choosing the areas and in harvesting the grain inclosed by the hoops is necessary to secure accurate results. Tests conducted at various times to check the accuracy of this method show that with reasonable care in choosing the hoop areas and harvesting them, the results are probably as dependable as those obtained by harvesting the entire plot. For example, a 0.4-acre field of alfalfa in 1913 estimated by this method to yield 1.5 tons actually produced 1.45 tons, and a 0.45-acre field of oats estimated at 29.4 bushels produced 28.3 bushels per acre. Hoop areas were taken from eight tenth-acre plots on the agronomy farm in 1914 and the plots then harvested in the usual way. The extreme variation in yield of grain secured by the two methods was 5.1 percent and the average 0.93 percent of the yield of the plots. In 75 percent of the plots the hoop method gave the highest yield, probably because of less loss in harvesting.

Kansas Agr. Expt. Station,
Manhattan, Kansas.

# INFLUENCE OF POSITION OF GRAIN ON THE COB ON THE GROWTH OF MAIZE SEEDLINGS.[1]

Byron D. Halsted and Earle J. Owen.

## Introduction.

Five sample ears from each of 20 representative varieties and crosses of corn were used in this experiment. The grains from each ear were divided into 10 equal lots, each representing a zone of the ear, ranging from the butt to the tip. The average weight of the grains in each zone of 2 of the 5 ears was obtained and then 25 kernels from each lot were planted an inch deep in a greenhouse bed. The grains for planting were taken at random, except that in the butt and tip zones the smallest perfect kernels were used. The plants were harvested after 17 days, a period sufficient to produce plants of considerable size.

The emergence of the tips of the seedlings was recorded daily, and from this the averages were obtained. At harvest time the viability was recorded and the weight and length of the seedlings taken, from which the vigor and variability were afterward deduced. By averaging the five units (ear belts) in each set a series of tables has been constructed that shows the relationship of the position upon the cob to the particular characters under consideration, as follows: (1) Weight of grain; (2) specific gravity of grain, (3) emergence of seedlings; (4) viability of seeds; (5) weight of seedlings; (6) length of seedlings, and (7) variability in length.

## Weight of Grain.

The names of the varieties used in the experiment and the weights of the grains in grams by zones are shown in Table 1.

The grains range in weight from those of the Hickory King, which are unusually large, to those of the Country Gentleman and the Golden Queen (pop), the immature kernels of the last being very small. The flint varieties generally have the heaviest grains, followed by the dent sorts, but the Black Mexican, Stowell Evergreen, and Golden Bantam, three standard sweet kinds, are near the average of the

[1] Contribution from New Jersey Agricultural Experiment Station. Received for publication January 5, 1917.

list of 20 here given. The cross between Hickory King and Golden Queen has a rank that is practically the mean of that of the two parents. Nearly the same is true of the cross of Golden Queen upon Champion White Pearl, and also of Golden Queen upon Brazilian Flour.

TABLE 1.—*Average weight of grains (in grams) of 20 varieties of corn, in each of 10 zones from the butt to the tip of the ear.*

| Variety. | Zone. | | | | | | | | | | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butt (1). | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | Tip (10). | |
| Longfellow | 0.43 | 0.44 | 0.43 | 0.42 | 0.42 | 0.40 | 0.39 | 0.37 | 0.35 | 0.31 | 0.396 |
| Hickory King | .52 | .55 | .56 | .53 | .53 | .51 | .48 | .46 | .46 | .42 | .511 |
| Golden Queen (mature) | .16 | .17 | .16 | .16 | .15 | .12 | .13 | .13 | .12 | .10 | .140 |
| Golden Queen (immature) | .06 | .06 | .07 | .07 | .07 | .07 | .06 | .05 | .04 | .03 | .058 |
| Champion White Pearl | .40 | .39 | .38 | .37 | .37 | .35 | .35 | .34 | .33 | .29 | .357 |
| Reid Yellow Dent | .29 | .29 | .28 | .28 | .27 | .26 | .24 | .22 | .20 | .17 | .250 |
| Iowa Silvermine | .32 | .32 | .32 | .31 | .31 | .29 | .28 | .27 | .27 | .24 | .293 |
| Boone County White | .40 | .38 | .38 | .37 | .35 | .34 | .33 | .32 | .31 | .28 | .346 |
| Wing 100-Day | .40 | .38 | .36 | .36 | .36 | .36 | .36 | .34 | .33 | .28 | .353 |
| Early Leaming | .34 | .35 | .35 | .34 | .32 | .32 | .32 | .31 | .31 | .29 | .325 |
| Brazilian Flour | .30 | .31 | .31 | .31 | .31 | .30 | .29 | .28 | .27 | .24 | .294 |
| Stowell Evergreen | .30 | .28 | .27 | .26 | .26 | .25 | .25 | .24 | .23 | .21 | .255 |
| Black Mexican | .28 | .30 | .29 | .29 | .29 | .28 | .27 | .26 | .23 | .20 | .269 |
| Country Gentleman | .18 | .15 | .15 | .14 | .14 | .13 | .13 | .14 | .12 | .11 | .139 |
| Golden Bantam | .26 | .27 | .27 | .27 | .26 | .26 | .24 | .23 | .21 | .18 | .245 |
| Crosby Early | .25 | .25 | .24 | .23 | .23 | .22 | .20 | .20 | .18 | .17 | .217 |
| Golden Queen × Hickory King | .26 | .28 | .29 | .28 | .28 | .27 | .27 | .25 | .23 | .18 | .259 |
| Squaw × Country Gentleman | .25 | .25 | .25 | .24 | .24 | .23 | .23 | .22 | .22 | .18 | .231 |
| Golden Queen × Champion White Pearl | .27 | .27 | .26 | .27 | .26 | .25 | .24 | .22 | .20 | .18 | .242 |
| Golden Queen × Brazilian Flour | .24 | .24 | .24 | .23 | .23 | .22 | .21 | .21 | .20 | .18 | .220 |
| Totals | 5.91 | 5.93 | 5.86 | 5.75 | 5.65 | 5.45 | 5.30 | 5.08 | 4.81 | 4.24 | |
| Averages | .296 | .297 | .294 | .288 | .283 | .272 | .265 | .254 | .241 | .212 | |

The tip zone of grains in all the 20 sets is the lightest, but in three kinds, Country Gentleman, Crosby Early, and Stowell Evergreen, the difference is small. In these the ears were unusually well filled over the tip. In the Country Gentleman, for example, the grains at the tip are noticeably broad but short and not of the "shoe peg" type characteristic of the grains in the middle of the ear. The same is true of the butt grains, which weigh more than those adjoining them in the second zone. This same peculiarity of broad, flat grains is met with in the Champion White Pearl, Boone County White, and Wing 100-Day. Quite generally, many of the ovules near the butt fail to

grow, possibly because of inherent weakness, failure to become fertilized, or because they are destroyed by the extra pressure of the closely fitting husks. Therefore, the grains that are formed are flat-topped, misshapen, and arranged without apparent order upon the cob. Had all the ovules at the butt developed, it is self evident that, conditions remaining the same, the grains would have been much smaller than they were found to be. This tendency of grains to expand when lateral pressure is removed has been shown by the larger size and nearly spherical shape of grains produced on ears that for this particular purpose had received very limited amounts of pollen, and, as a consequence, produced only a few scattered grains.

It is seen that the zone next above the butt leads in weight, with the butt zone a close second, and that the decrease is quite uniform from the third zone to the tip. A long ear that tapers both ways from the second zone would visually represent the results that have been obtained.

### Specific Gravity.

The range in specific gravity is from 1.35 in Golden Queen to 1.16 in Brazilian Flour. In the first kind the grains are small, and the endosperm is chiefly corneous, while in the last the grains are large, with a chalky or floury endosperm. The sweet corns have a high specific gravity, Golden Bantam and Stowell following close to the Golden Queen, with Country Gentleman, Black Mexican, and Crosby not far behind. This high range of specific gravities in the sweet grains is doubtless due to the low starch and high sugar content and the conséquent drying down of the endosperm into the horny texture, which is quite comparable with that of the pop and flint corns. The crosses between Golden Queen and Brazilian Flour, the highest and the lowest in the list for specific gravity, give nearly the mean of the two extremes, namely, 1.26. The cross of Golden Queen upon Champion White Pearl gives 1.26, which is close to the specific gravity of the mother parent, and in like manner the Golden Queen upon Hickory King cross shows a specific gravity quite close to that of the Hickory King.

There is a remarkable difference between the specific gravity of mature and of immature grains of the Golden Queen. The immature grains were the lightest with the exception of the Brazilian Flour previously mentioned. In other words, the specific gravity of the Golden Queen grains fell from the first place to the last but one because of immaturity. This test illustrates the importance of select-

ing for the present study only ears that were well filled and showed no sign of immaturity; and with the single exception purposely made, this was done with extreme care.

The sixth zone from the butt is highest in specific gravity, with the fifth and fourth zones next in order, followed closely by the third and the seventh zones. The three lowest specific gravities are at the tip end, and the fourth lowest at the butt. In a general way the specific gravity decreases in both directions somewhat regularly from the middle of the ear. By making five groups from base to tip, the sums of the ranking figures are as follows: 9, 15, 19, 9, 3. This shows that the decrease is much more rapid in the upper than in the lower half of the ear. When three groups only are made, namely, the basal three, the middle three and the upper four zones, the averages of the specific gravities are: 1.25, 1.26, and 1.24.

The ranking of the specific gravities does not coincide with that for weights of grains, as the following parallel display shows:[2]

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank of weight of grains | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Rank of specific gravity | 4 | 5 | 7 | 8 | 9 | 10 | 6 | 3 | 2 | 1 |
| Sums | 13 | 15 | 15 | 15 | 15 | 15 | 10 | 6 | 4 | 2 |

Only the three upper zones show the same rank for both weight and density. The three lower zones, while the heaviest, have a medium specific gravity, and the next three with the greatest specific gravity are only medium in weight.

## Emergence.

As the temperature of the air and soil of the greenhouse was not constant during the winter months when the tests were conducted, no rational comparison of the emergences is possible. If one disregards the variation in temperature, it follows that the Wing 100-Day, Early Leaming, Champion White Pearl, and Iowa Silvermine are quick growing, while, on the other hand, Brazilian Flour, Golden Queen, Hickory King, and Longfellow are comparatively slow.

From the grand averages for all the zones it is found that the time consumed from the planting to the showing of the tip at the surface of the ground is somewhat less than one week (6.44 days). The butt zone required the shortest time for emergence, a trifle over 6

[2] The number 10 stands for highest and from it the series descends in regular order to 1, the lowest.

days, while the zone next above it needed 10 hours longer, and was the slowest zone upon the ear. It is further found that there is a fairly uniform decrease in time for emergence from the second to the tenth zone. When the ranks of emergence are compared with those of weight of grain, it is seen that there is a close correspondence, that is, a high weight is associated with a low rate of emergence. This is shown in the following table, which gives the ranking of the ten zones for all the 100 ears.

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank of weight of grains | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Rank of emergence of seedlings | 1 | 10 | 9 | 8 | 6 | 7 | 5 | 2 | 4 | 3 |
| Sums | 10 | 20 | 17 | 15 | 12 | 12 | 9 | 5 | 6 | 4 |

The exception to the general rule is found in the butt zone, where the grains rank next to the largest, and their seedlings were the first to emerge. This result is accounted for in part by the fact that the smallest grains of this zone were planted. Furthermore, the kernels were much compressed and misshapen and therefore they exposed an absorbing surface relatively, if not actually, greater than that of the grains from the other portions of the cob.

### Viability.

The viability of the grains of a large portion of the samples was high, the general average being 91.91 percent. This includes the set of immature ears of the Golden Queen, which had a viability of 67.87 percent, with Brazilian Flour only a little better (76.94 percent) and Stowell Evergreen not far ahead. The most viable sets were Iowa Silvermine and Early Leaming, both with 98.72 percent viability, followed closely by a cross of Golden Queen upon Champion White Pearl (97.92 percent), the viability of the parents being nearly the same, namely, 96.96 percent and 96.56 percent, respectively. With the exception of the Brazilian Flour (and, of course, the immature Golden Queen), the sweet corns as a group were the least viable, a result that has always been observed in previous comparative studies of viability in corn.

The results show further that the greatest viability is in the fourth zone, with an average of 94.44 percent, and the lowest at the butt (87.68 percent), followed closely by the tip. The best five zones for ability to produce seedlings are contiguous in the middle of the ear, leaving two at the butt and three at the tip to compose the poorer half.

The ears were too well selected to yield any striking differences in viability as associated with place upon the cob.

The following tabulation of the ranking figures shows that the weights, specific gravities, and viabilities are associated.

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank of weight of grains | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Rank of specific gravity | 4 | 5 | 7 | 8 | 9 | 10 | 6 | 3 | 2 | 1 |
| Rank of viability | 1 | 3 | 4 | 10 | 7 | 9 | 6 | 8 | 5 | 2 |
| Sums | 14 | 18 | 19 | 25 | 22 | 24 | 16 | 14 | 9 | 4 |

The heavier grains are in the lower half of the ear, but those of greater density and viability occupy the middle zones of the cob.

## Vigor.

Vigor is here recorded as the live weight of the seedlings from which that of the grain itself has been deducted. An error is introduced into this method by the fact that the original grain coats, containing much of the original food substances and considerable water, adhere to the seedlings. It was found too difficult to remove these watery kernels before weighing, and therefore the results are all somewhat too high, but the error in all instances is probably a fairly uniform one.

Furthermore, there is a variable time factor that should be mentioned, namely, that there are several hours' difference between the emergence of the seedlings of the smaller grains and those of the slower growing plants from the larger grains upon the same ear, usually those near the tip and butt. This difference in germination, therefore, favors the seedlings from grains borne at the extremities of the ears, and makes the recorded differences somewhat less than they should be.

A comparison of the ranking columns of the size of grains with those of seedling vigor shows a positive correlation. The data on live weight of the seedlings are given in Table 2.

From Tables 1 and 2 it is seen, for example, that the Hickory King is first in weight of grain and vigor of seedlings, while the immature Golden Queen is lowest in both these characters. Contrariwise, the mature Golden Queen, among the lightest of all the mature sets, is next to the lowest in vigor of the seedlings. There is a great lack of vigor in the comparatively large butt grains as shown in the display of ranking figures which immediately follows Table 2.

TABLE 2.—*Vigor of seedlings as indicated by their live weight in grams, as related to the position of the kernel on the cob.*

| Variety. | Zone. | | | | | | | | | | Average. | Rank. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| Longfellow | 2,266 | 2,386 | 2,238 | 2,428 | 2,404 | 2,444 | 2,366 | 2,224 | 2,328 | 1,692 | 2,277 | 14 |
| Hickory King | 2,870 | 3,034 | 3,042 | 3,276 | 3,330 | 3,166 | 3,018 | 3,090 | 2,888 | 2,830 | 3,050 | 20 |
| Golden Queen (mature) | 1,000 | 1,186 | 1,176 | 1,148 | 1,182 | 1,184 | 1,038 | 1,094 | 1,044 | 768 | 1,082 | 2 |
| Golden Queen (immature) | 351 | 410 | 447 | 433 | 407 | 375 | 354 | 303 | 256 | 225 | 356 | 1 |
| Champion White Pearl | 2,722 | 3,120 | 2,834 | 3,004 | 2,960 | 2,872 | 2,698 | 2,694 | 2,642 | 1,900 | 2,744 | 16 |
| Reid Yellow Dent | 1,202 | 1,468 | 1,466 | 1,496 | 1,526 | 1,468 | 1,366 | 1,272 | 1,214 | 916 | 1,339 | 4 |
| Iowa Silvermine | 2,282 | 2,556 | 2,630 | 2,682 | 2,412 | 2,452 | 2,444 | 2,358 | 2,286 | 1,638 | 2,374 | 16 |
| Boone County White | 2,128 | 2,214 | 2,250 | 2,242 | 2,296 | 2,100 | 2,178 | 2,156 | 2,076 | 1,702 | 2,134 | 12 |
| Wing 100-Day | 2,128 | 2,310 | 2,234 | 2,192 | 2,180 | 2,286 | 2,240 | 2,172 | 2,916 | 1,398 | 2,105 | 11 |
| Early Leaming | 2,140 | 2,368 | 2,314 | 2,220 | 2,138 | 2,138 | 1,980 | 2,172 | 2,030 | 1,748 | 1,911 | 9 |
| Brazilian Flour | 708 | 1,074 | 1,298 | 1,180 | 1,358 | 1,202 | 1,254 | 1,250 | 1,280 | 952 | 1,155 | 3 |
| Stowell Evergreen | 2,662 | 2,590 | 2,742 | 2,568 | 2,398 | 2,450 | 2,456 | 2,350 | 2,246 | 2,010 | 2,447 | 17 |
| Black Mexican | 1,730 | 1,988 | 2,058 | 2,138 | 2,088 | 2,000 | 1,970 | 1,996 | 1,766 | 1,352 | 1,908 | 8 |
| Country Gentleman | 1,792 | 2,336 | 2,062 | 1,990 | 1,904 | 1,764 | 1,738 | 1,638 | 1,196 | 1,300 | 1,832 | 6 |
| Golden Bantam | 2,178 | 2,438 | 2,426 | 2,590 | 2,256 | 2,428 | 2,466 | 2,360 | 2,198 | 1,652 | 2,326 | 15 |
| Crosby Early | 2,520 | 2,596 | 2,672 | 2,610 | 2,624 | 2,590 | 2,526 | 2,428 | 2,466 | 2,360 | 2,198 | 18 |
| Golden Queen × Hickory King | 1,546 | 1,846 | 1,918 | 1,930 | 1,952 | 1,910 | 1,884 | 1,744 | 1,786 | 1,258 | 1,777 | 5 |
| Squaw × Country Gentleman | 1,688 | 2,016 | 2,020 | 2,064 | 1,988 | 2,000 | 1,938 | 1,982 | 1,866 | 1,422 | 1,898 | 7 |
| Golden Queen × Champion White Pearl | 2,070 | 2,440 | 2,428 | 2,436 | 2,272 | 2,408 | 2,204 | 2,094 | 1,938 | 1,430 | 2,272 | 13 |
| Golden Queen × Brazilian Flour | 1,884 | 2,130 | 2,064 | 2,032 | 1,928 | 2,036 | 1,832 | 1,814 | 1,810 | 1,754 | 1,928 | 10 |
| Averages | 1,893 | 2,125 | 2,116 | 2,133 | 2,094 | 2,064 | 2,010 | 1,966 | 1,896 | 1,503 | 1,980 | |
| Rank | 2 | 9 | 8 | 10 | 7 | 6 | 5 | 4 | 3 | 1 | | |

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rank of weight of grains | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Rank of vigor of seedlings | 2 | 9 | 8 | 10 | 7 | 6 | 5 | 4 | 3 | 1 |
| Sums | 11 | 19 | 16 | 17 | 13 | 11 | 9 | 7 | 5 | 2 |

The explanation of this may be found in the unfavorable conditions for germ development at the butt. So far as these results go it is shown that in respect to vigor the best grains are to be found in the lower half of the ear, with the exclusion of the kernels at the butt. The upper half shows a uniform decrease in vigor from the sixth zone to the tip.

With the single exception of the butt zone, the weight for the grains increases from the butt to the tip.

The specific gravity is highest in the grains of the middle half of the ear.

SUMMARY.

TABLE 3.—*Ranking of averages of the seven points considered.*

| Character. | Zone. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Weight of grain | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Specific gravity | 4 | 5 | 7 | 8 | 9 | 10 | 6 | 3 | 2 | 1 |
| Emergence | 1 | 10 | 9 | 8 | 6 | 7 | 5 | 2 | 4 | 3 |
| Viability | 1 | 3 | 4 | 10 | 7 | 9 | 6 | 8 | 5 | 2 |
| Vigor | 2 | 9 | 8 | 10 | 7 | 6 | 5 | 4 | 3 | 1 |
| Length of seedling | 2 | 3 | 9 | 10 | 8 | 7 | 6 | 5 | 4 | 1 |
| Variability | 10 | 8 | 3 | 5 | 4 | 2 | 6 | 1 | 7 | 9 |

The emergence is least rapid in seedlings from grains borne in the middle of the ear; and is correlated with specific gravity, that is, the lighter the grain, the more rapid the initial growth.

Between viability and vigor there is a strong positive correlation, that is, the more viable the more vigorous, and the same is naturally true of the length of the seedling.

Variability is evidently correlated with weakness—but to establish the degree, measurements of more than 2,500 seedlings are required. In other words, viability and vigor are negatively correlated with variability. A set of strong plants is more uniform than one of weak seedlings.

The position on the cob has much influence upon the variability, which may be due to size as well as to maturity and nourishment of the grains.

A practical application of the results above given would consist of germinating a liberal sample, say 20 kernels, from two rows upon opposite sides near the middle of the ear. Select only those ears that show practically 100 percent viability, and plant from only the middle of the ear, that is, reject all grains of the butt zone and of the four zones of the upper portion of the ear.

This suggestion does not interfere with any rules in corn selection now in practice, but simply is a far more rigid application of the method of "nubbing," namely, the discarding of a few grains at the butt and tip of the ear, now recommended by corn experts and practiced by growers to a limited extent.

# THE HANDLING AND STORAGE OF SPRING WHEAT.[1]

C. H. Bailey.

The greater part of the small-grain crop of commerce grown in the Great Plains area and the eastern part of the United States is handled in bulk. Certain factors involved in the successful handling and storage of grain vary, depending upon whether it is handled in bulk or in sacks. In the first place, there is less opportunity for change in the moisture content of bulk grain. Slight reductions in moisture content may result when relatively damp grain is handled on a hot day, while a slight increase may occur when very cold grain is exposed in a warm, humid atmosphere. In general, however, the moisture content of spring wheat is determined principally by the climatic conditions prevailing between harvesting and thrashing. If this period is warm and dry the grain will be well cured when it starts on its journey to the consumer; rain on the unthrashed bundles, particularly if exposed in the shock, results in damp, "tough" wheat that will cause difficulties in handling and storing.

The fact that wheat is a relatively poor conductor of heat introduces another variable in handling wheat in bulk as compared with handling in sacks. The heat which develops when damp wheat is stored does not pass off as rapidly from a large bulk as from a smaller one, such as exists when sacks are piled in narrow stacks. The more rapid the transfer of heat from a fermenting mass to a cooler surrounding medium (usually air) the less the likelihood of serious damage. This is assuming that the moisture content of the grain is sufficiently low to preclude germination.

Spring wheat is not biologically ripe at the time it is usually harvested. The post-harvesting process of ripening is attended by certain peculiar phenomena. If the bundles are in a stack they take on a moist condition. This process is commonly called "sweating," and is undoubtedly accompanied by biochemical changes resulting from enzymic activities within the kernel. If the sweating process occurs in normal wheat in the bin, a slight rise in temperature may result,

[1] Read at the Second Inter-State Cereal Conference, University Farm, St. Paul, Minn., July 11, 1916. Published, with the approval of the Director, as Paper No. 62 of the Journal Series of the Minnesota Agricultural Experiment Station. Received for publication April 20, 1917.

The baking quality of the flour is improved by these changes in the grain.

There are several factors which determine whether or not grain will spoil in storage after it has passed through the sweat. First, and most important, is the percentage of moisture in the kernels when they are stored. The form in which moisture exists in the kernel is of interest in this connection. Organic colloids of the nature of those which form the principal constituents of the wheat kernel have the property of imbibing considerable quantities of water and forming elastic gels. The colloidal gel swells considerably, although the total volume of the water plus the dry colloid diminishes. The water-imbibing capacity of the several colloids varies widely. Thus starch has only about one-fourth the imbibing capacity of wheat gluten. There is no fixed amount which a given dry colloid will imbibe; thus gels of varying viscosity can be produced, depending upon the proportion of water present and upon other variables, such as temperature, mineral salts, and other substances. The rate of diffusion in a gel varies with the viscosity; in dilute gels diffusion takes place as in water, while in strong gels the rate is slower.[2] It is probable that in dry grain the imbibed water is not sufficient to produce a gel, i. e., the colloidal material does not have a continuous structure. The possibilities of diffusion are decidedly reduced under such conditions.

The exact percentage of moisture below which this discontinuous structure exists is not known; it probably varies with the percentage of gluten in the grain, since gluten possesses a greater water-imbibing capacity than starch. Increasing the moisture content above the maximum at which discontinuity exists results in the formation of an elastic gel through which diffusion can occur. Further increases in moisture content up to saturation (maximum imbibition) produce progressively less viscous gels, and correspondingly increase the rate of diffusion. Since the rate of respiration in grain doubtless depends in part upon the rate of diffusion between the various kernel structures, it follows that the less viscous the gelatinous material of which the cell contents are composed the more rapid the production of heat through respiration. To restate, the production of heat is dependent upon the activity of the oxidases of the kernel, the complex phenomena being known as respiration. The latter is accelerated by an increase in the rate of diffusion, which in turn is dependent upon the existence of a gel, and the viscosity of that gel. For these reasons the moisture content of the grain determines to a considerable extent

[2] Plimmer, R. H. A. Practical organic and biochemistry, p. 386. New York, 1915.

the liability of heating when bulk grain is stored, and also the rate at which the respiration and consequent heating will occur.

To ascertain the percentage of moisture which spring wheat may contain without heating in store, the Minnesota Grain Inspection Department and the State Boards of Grain Appeals, in cooperation with the Division of Agricultural Chemistry of the University of Minnesota, obtained permission from one of the large elevator companies of the State to make observations in grain stored by them. About twenty lots of wheat were experimented with, containing from 12.76 to 17.45 percent of moisture. No lot represented less than a carload (1,200 to 1,400 bushels). These observations were made through a period of more than one year, covering two summer seasons and the intervening winter. The data are too voluminous to be given in detail in this paper. It was concluded that hard spring wheat of reasonable plumpness, containing less than 14.5 percent of moisture, is not likely to heat when stored under normal conditions in a temperate climate, while similar wheat containing 15.5 percent or over of moisture is practically certain to heat. Between these limits the possibility of heating depends upon other conditions which are discussed later in this paper.

The rate of heating in its relation to moisture content is shown in figure 16. Two lots of wheat are here compared with regard to the time required to become actively heating. One carload contained 15.5 percent, the other 16.5 percent of moisture. They were put in inside elevator bins on September 11 and 12 respectively. The lot containing 15.5 percent of moisture kept 333 days without heating sufficiently to necessitate turning and cooling, while that which contained 16.5 percent had to be run and cooled in 49 days. Had these been stored in the spring or summer, the time elapsing before heating began would have been much shorter, but the cold fall and winter weather which intervened resulted in the heat being lost into the air or surrounding material so fast as to preclude a rapid rise in temperature.

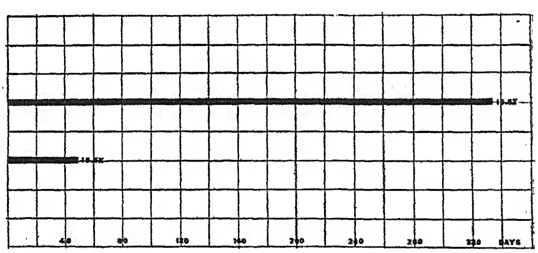

FIG. 16. Graph showing relation between moisture content and rate of heating.

This leads to a consideration of the relation of air temperature to the rate of heating. The lot of wheat containing 16.5 percent of

moisture, mentioned in the foregoing paragraph, required from September 12 to October 31 to rise from 70° to 80° F. and require attention. The mean air temperature during this interval was 44.3°. Another lot of similar wheat, containing the same percentage of moisture, had been stored July 28, and the temperature of it rose from 70° to 80° F. in 11 days, the mean air temperature of this interval being 62.1°. These data are graphically shown in figure 17. The difference in the rate of heating was due to the greater rate of heat loss into the cold atmosphere in the fall. While this difference might not have been so great in a larger mass of grain, it shows the effect of seasonal influences.

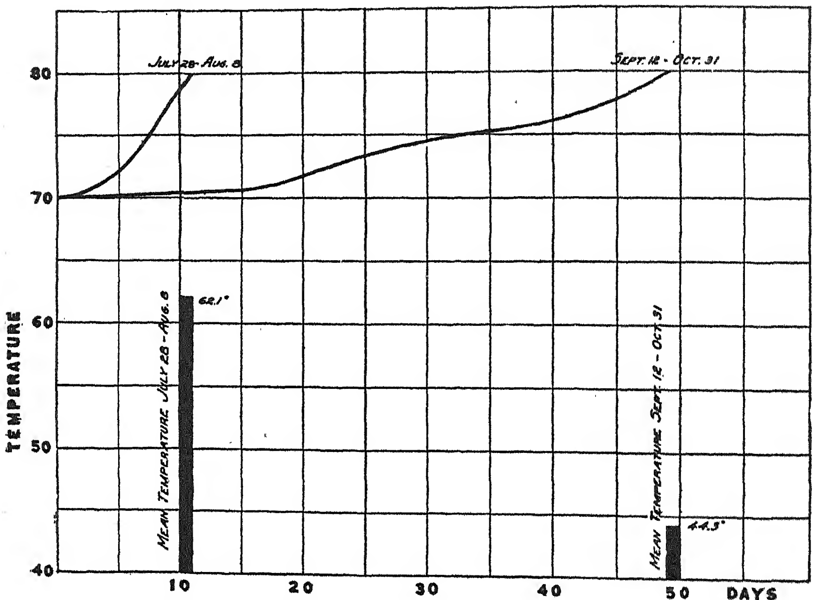


FIG. 17. Graph showing effect of atmospheric temperature on the rate of heating.

The location of the bin in the elevator may have considerable to do with the rate of the loss of heat from the grain. This is shown by experiments conducted with a car of wheat containing 17.5 percent of moisture which was stored in an outside bin in a steel elevator on September 10, and kept until June 10 the following year, a total of 303 days. Its record is compared in figure 18 with that of a car containing 16.5 percent of moisture which was put in an inside bin at the same time and had to be run and cooled in 49 days.

The initial temperature of the grain is also significant. This is

shown by the records of bins 32a and 158b. Both were filled at almost the same time with wheat containing 16.5 percent of moisture. The initial temperature of that in bin 158b, as shown in figure 19, was 74° F., while that in bin 32a was 70°. It took the latter over five times as long to reach a temperature of 80°. These data

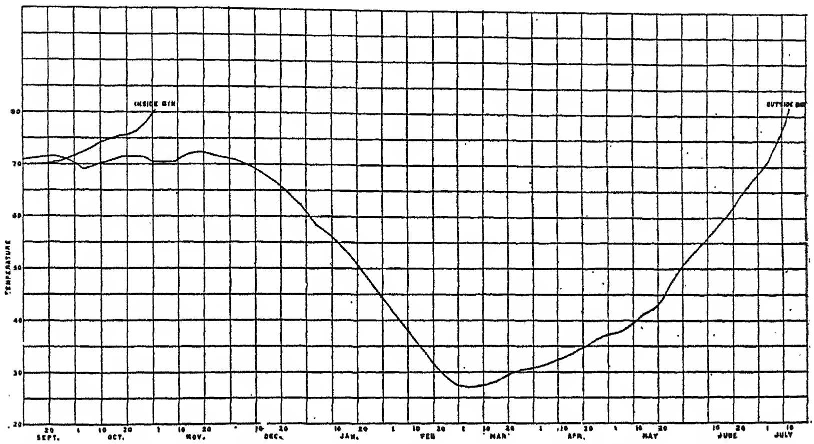

FIG. 18. Graph showing relation of the location of the grain in the elevator during the winter months to the rate of heating.

also illustrate the acceleration of respiration with a rise in temperature, the curve being logarithmic in form, and the rate very rapid as the temperature approaches 80°.

When uniformly mixed wheat heats as the result of respiration, the highest temperatures are usually reached near the surface. The exact location of the warmest portion varies with the weather. When the surrounding air is cold, as in midwinter, it is usually from 15 to 20 feet below the surface, while in mild or hot weather it is likely to be at a depth of from 5 to 8 feet. The changes in temperature at different depths are shown in figure 20, which gives the record of a bin of wheat that was at freezing temperatures on April 4, and

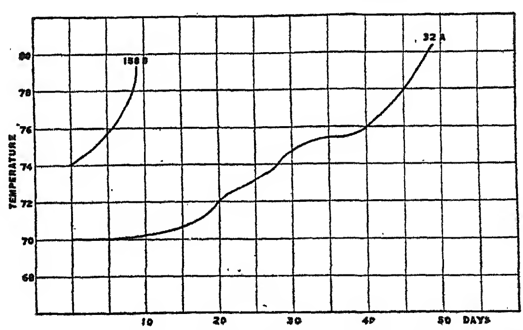


FIG. 19. Graph showing relation of the original temperature of the grain to the rate of heating.

was heating on July 10. At this time the temperature of the grain surrounding bulb 5, at a depth of 8 feet, was 81° F., while bulbs 4, 3, 2, and 1, which were at depths of 18, 28, 38, and 48 feet, respectively, were in grain at temperatures of 70°, 65°, 62°, and 62°. The larger quantity of oxygen available to support aerobic respiration in the kernels near the surface no doubt is responsible for the more rapid rise in temperature in that portion; the heat produced in the surface layers is lost into the surrounding atmosphere, however, and consequently the highest temperature is reached at a depth of a few feet.

The material of which the bin is constructed affects the keeping qualities of damp grain in just the proportion that it affords heat insulation. The four materials used in bin construction are ranked in heat-insulating value by the leading elevator construction companies of Minneapolis as follows: (1) Hollow tile, (2) wood, (3) concrete, and (4) steel. In cold weather the better the conductor in which the grain is stored and the more exposed the location, the less rapidly will damp wheat heat. In hot weather the reverse is true, since the heat of the air will be transmitted to the grain through a poor insulator, and the rate of respiration accelerated through the resultant rise of temperature.

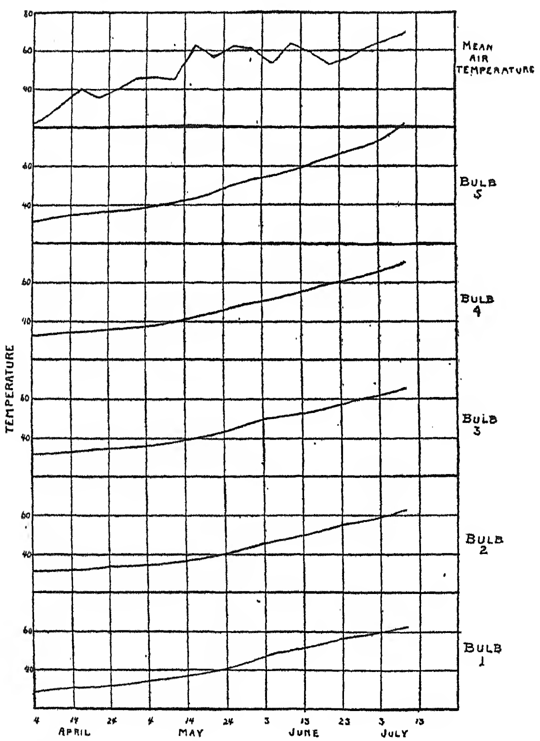


FIG. 20. Graph showing temperatures recorded at different depths in a bin of grain.

To recapitulate briefly, the handling of wheat in bulk introduces certain difficulties which do not exist to so great an extent when it is handled in sacks. Wheat which is not perfectly ripe when harvested

"sweats" either in the shock, stack, or bin. If normally dry, this sweating improves the baking qualities of the flour. The maximum limits of moisture which hard spring wheat may contain without danger of heating in a temperate climate are between 14.5 and 15.5 percent. Whether it actually heats or not depends upon several factors, including the hardness of the kernels because of the relation of kernel density to gluten content, the size or dimensions of the bulk, temperature of the atmosphere, initial temperature of the grain, location and consequent exposure of the bin, and the material of which the bin is constructed.

Section of Cereal Technology,
Division of Agricultural Biochemistry,
University of Minnesota,
and
Minnesota Grain Inspection Department Laboratory.

## THE COLOR CLASSIFICATION OF WHEAT.[1]

The color classification of wheat was discussed by the Minnesota Section of the American Society of Agronomy during the first months of its organization. The subject was first discussed by H. K. Hayes of the Section of Plant Breeding, and a committee was appointed to devise a scheme which could be employed by all who had occasion to use such a system of classification. A set of samples was prepared by A. C. Arny and P. J. Olson which illustrated the various divisions provided for in this system. The report of this committee was subsequently adopted by the local section, which authorized its publication in the Journal of the society. This report is presented in the following paragraphs.

The visual appearance of wheat which is commonly termed color is due to the joint effect of two factors: First, the presence or absence of a brownish-red or orange-yellow pigment in the bran layer, and second, the physical condition of the endosperm cells. The latter may be corneous or starchy, depending upon the density of the cell contents or the relative amount of space occupied by air cavities or vacuoles. The confusion which has arisen in regard to color classification is probably due to the use of a single term to describe the combined visual effect of these two characters mentioned above.

[1] Prepared by a Committee of the Minnesota Section of the American Society of Agronomy, consisting of Messrs. H. K. Hayes, C. H. Bailey, A. C. Arny, and P. J. Olson. Received for publication March 17, 1917.

That there is such a confusion is probably recognized by every one who has any knowledge of the present methods of classifying the color of wheat.

The present state of ideas is illustrated by the test conducted by H. K. Hayes. Six samples of wheat were submitted separately to several members of the experiment station staff, who were asked to classify them for color. The samples employed were:

1. Preston, a red spring wheat.
2. Turkey, a hard red winter wheat.
3. Harvest King, a red winter wheat common in the East, which under University Farm conditions is less corneous than Turkey.
4. Kubanka, a durum wheat.
5. Soft white wheat from the Pacific Coast.
6. Preston selection which lacks red pigment in the bran layer.

Three of the men who classified the samples used the term "amber" to describe color, and modified it by the use of such adjectives as "dark," "light," "very light," etc. There was no consistent use of the defining adjective, however, and what one man termed "light amber" was called "dark amber" by others. A fourth classification used the term "amber" to express the appearance of corneous durum and other wheats which lack red pigment, and modified it by the use of the term "red" to denote a corneous wheat with red pigment. The objection to this method is the use of a single term to express lack of bran pigment combined with a corneous endosperm. Three other men classified the samples by the use of two columns, one for pigmentation, the other for density of endosperm. There was no uniformity in the use of terms on the part of these men, however. This test indicated the need of a uniform method of color classification, and prompted the appointment of the committee which renders this report.

It is generally recognized that the presence or absence of a red pigment in the bran layer is of little importance in indicating milling value, since there are certain unpigmented varieties which possess as good milling qualities as many of the pigmented varieties. The physical condition or density of the endosperm is of considerable importance because of its relation to milling properties and bread-making qualities. The relative stability of these two characters is of significance in a discussion of color classification. The first of these characters, pigmentation, is definitely inherited, and exhibits itself under widely varying conditions of environment. Although modified to some extent by climatic conditions the intensity of pig-

mentation is a varietal character as well; some varieties possessing a less degree of pigmentation than others. With the same degree of pigmentation, a starchy kernel possesses a lighter appearance than a corneous kernel, however, but there is no difficulty in separating a starchy pigmented kernel from a starchy white kernel.

If we consider that inheritance is a characteristic manner of reacting to a certain environment, we may say that the physical condition, whether corneous or starchy, is an inherited character. Unlike the pigment, however, the density of the endosperm is very dependent upon environmental conditions. Thus, at University Farm, no wheats would be constantly starchy, although some varieties are consistently softer than others. Even though this character is easily influenced by environmental conditions, it is of such importance, because of its relation to milling qualities, that a classification under this head is necessary for the breeder, farm crops expert, or milling chemist.

The following scheme of classification is accordingly proposed. Columns headed (1) *Pigmentation,* and (2) *Physical condition or density* are necessitated. Under pigmentation the use of the term "red" to denote the presence of a brownish-red pigment in the bran layer is proposed. This is to be modified by the term "light" when the degree of pigmentation is less than is usual in red wheats. While the pigment may not be entirely absent from the bran layer of the so-called "white wheats," it is so nearly so that the term "white" is proposed in classifying them. It is recognized that a corneous kernel with a nonpigmented bran layer will not appear to be perfectly white; so far as the color of the bran layer is concerned, it is not affected by the density of the endosperm, however, although the complex of visual appearance due to the two factors is influenced by the relative endosperm density.

Under physical condition or density it is proposed that four terms be employed to denote the several gradations of endosperm density. These are (1) corneous, (2) subcorneous, (3) substarchy, and (4) starchy. Under group 1, corneous, would be included only the uniformly corneous samples. Group 2, subcorneous, would include samples containing kernels which approach either of the following conditions or a combination of both,—(*a*) samples containing ⅔ corneous kernels and ⅓ starchy or substarchy and (*b*) samples in which nearly all kernels approach the corneous group, the greater part of the kernels having only a small percentage of starchy endosperm. Group 3, substarchy, consists of kernels ⅔ of which are

starchy and ⅓ corneous or kernels which contain a small amount of corneous matter with the larger part of the endosperm starchy, or a combination of these two conditions. Group 4 would be limited to the uniformly starchy material. It is recognized that a sample will often be found to be intermediate between two of these groups; in such cases it must be classified in the group which it most nearly resembles. The plus (+) and minus (—) signs may be employed to designate that it varies somewhat above or below the average of the group to which it is assigned in point of relative density.

The application of the proposed system to the six wheat samples mentioned above would result as follows:

| Sample. | Pigmentation. | Physical condition or density. |
|---|---|---|
| 1 | Light red | Subcorneous |
| 2 | Red | Corneous |
| 3 | Light red | Substarchy |
| 4 | White | Corneous |
| 5 | White | Starchy |
| 6 | White | Subcorneous |

MINNESOTA SECTION,
AMERICAN SOCIETY OF AGRONOMY.

# THE ACTION OF PRECIPITATED MAGNESIUM CARBONATE ON SOILS.[1]

W. P. KELLEY.

## INTRODUCTION.

During recent years many investigations have been made on the lime-magnesia ratio in relation to plant growth. Different aspects of the question have been studied and many interesting experimental data obtained. In a large part of this work the attention of the investigator has been given mainly to the growth and yield of the crops employed. Just as in the study of many other soil problems, the final effects produced on the growing plant have been assumed to be brought about by the direct action of the substance applied. Consequently, attention has been focused on the physiological response on the part of the higher plant with only an occasional inquiry into the factors lying between the application and the response noted. It is obvious, therefore, that in such cases the soil has been looked upon as being in a state of stable equilibrium.

However, it is well known that, while soils without artificial treatment tend to undergo more or less continual change, the application of various substances, both organic and inorganic, frequently induces various reactions in soils. And while knowledge regarding the specific nature of such reactions is very imperfect, sufficient is known to justify the statement that artificial applications produce changes of a greater or less degree in the chemistry, physics, and microbiology of soils generally, and that some, at least, of these changes can scarcely fail to reflect themselves on the physiological behavior of growing crops.

It has been recognized for some time that the addition of soluble salts produces interchange of bases in soils, that the interchange when salts of different cations are added is not necessarily molecularly proportionate, and that it is rarely safe to predict from observations with one soil concerning the extent of interchange that will take place in another, since the rate of double decomposition in soils is quite variable. Nevertheless, the results of various experiments in-

[1] Paper No. 43, University of California, Citrus Experiment Station, Riverside, Cal. Received for publication July 2, 1917.

volving the use of soluble salts have frequently been discussed by writers on the subject as if the soil were incapable of being reacted upon by the substances applied. Many references bearing on this point can be cited. Among such may be mentioned certain studies with the use of soils from the semiarid west on the effects produced by the addition of various soluble salts (3, 10, 11, 12).[2]

Consideration of the principles of physical chemistry suggests, also, that other points of chemical equilibrium must necessarily be shifted as a result of the addition of soluble substances to soils. For example, it has recently been demonstrated in this laboratory that sodium carbonate is readily formed, in accordance with the principles of mass action, when sodium nitrate or other sodium salts are added to certain semiarid soils that contain calcium carbonate. In view of the ready solubility of sodium carbonate, the reaction of the soil solution must likewise be affected. Of course the reaction of soils may also be affected by the direct application of alkaline substances, such as carbonates, but in general these aspects of soils have not been sufficiently recognized in studies involving the application of chemical substances. Especially is this true in the investigation on the lime-magnesia ratio.

A number of compounds of calcium and magnesium have been employed in studies on the lime-magnesia ratio. One of the widely used compounds is the precipitated carbonate of magnesium. In certain cases the effects produced by this substance have been quite unlike those following the application of other magnesium compounds. In 1904, Meyer (15) recorded the results of pot experiments with the use of chloride, sulfate, citrate, and carbonate of magnesium and calcium carbonate. The experiments were conducted in a sandy loam soil with mustard as the test crop. The results were very striking, as is shown by the following data. The total yield from three pots without the application of any substance was 43.5 grams; with magnesium chloride, 40.5 grams; with magnesium sulfate, 50.1 grams; with magnesium citrate, 150.5 grams; with magnesium carbonate, 146.0 grams; and with calcium carbonate, 139.5 grams. These data show that, while the chloride and sulfate of magnesium produced only slight effects, the citrate and carbonate and also the calcium carbonate produced very striking stimulation.

In still other experiments, Meyer found that the use of relatively large quantities of magnesium carbonate resulted in reduced yields

[2] Numbers in parentheses refer to papers similarly numbered in the bibliography on p. 295.

in the case of rye, oats, lupines, peas, and carrots. In some cases a given quantity of magnesium carbonate prevented growth altogether, while smaller quantities produced stimulation. In general Meyer found that the simultaneous addition of calcium carbonate and magnesium carbonate produced much the same effect as either when applied alone. It is probable that the results obtained from the use of magnesium carbonate and citrate and of calcium carbonate were due in considerable part to effects on the reaction of the soil rather than to modification of the lime-magnesia ratio.

Hopkins (4) likewise found that while the application of magnesium carbonate in quantities up to 0.8 percent of the soil produced notable stimulation in the yield of wheat in pot cultures, the addition of 1.2 percent. or more produced marked diminution in yield. In some cases complete failure of the crop was reported. These results likewise were probably due to changes in the reaction of the soil rather than to changes in the lime-magnesia ratio, as has already been pointed out by Gile (2).

Many other citations could be made to the use of magnesium carbonate, the results of which are susceptible of the same interpretation. In fact, the literature[3] on this subject contains many references to experiments from various parts of the world in which it has been found that magnesium carbonate has produced injurious effects.

In this connection it may be mentioned that burnt lime high in magnesia has long been looked upon as being likely to produce injury to vegetation. The older writings on agriculture (17) contain frequent reference to this fact. In general it has been assumed that the injury in such cases was due to excessive alkalinity occasioned by the magnesia. With few exceptions it appears, however, that excessive alkalinity has not been seriously considered in connection with the injury produced by precipitated magnesium carbonate.

In 1912 the writer (5) began the study of the lime-magnesia ratio in relation to the biochemical formation of ammonia and nitrate in soils. The precipitated carbonates were employed as sources of calcium and magnesium and dried blood as the source of nitrogen. Two types of sandy soil from California were used. Later a more extended investigation of the same general nature was made with a considerable range of soils from the Hawaiian Islands (6, 7).

[3] The reader is referred to a very complete bibliography of this subject by C. B. Lipman, Plant World, v. 19, no. 4, p. 83–115, and no. 5, p. 119–131. 1916. In the latter of these papers, Professor Lipman also makes reference to some original experiments in California in which magnesium carbonate has proved to be injurious to plant growth.

In these investigations the methods that have been widely used among American bacteriologists were employed. Briefly, the method as used consisted in incubating portions of soils with varying amounts of magnesium and calcium carbonate, after first having added 1 to 2 percent of nitrogenous substance (dried blood, soy bean cake meal, or ammonium sulfate) and sufficient sterile water to produce suitable moisture content. After fixed periods of seven and twenty-one days, respectively, the ammonia and nitrates were determined. The results thus obtained formed the basis of considerable discussion.

It is not necessary at this time to discuss the several details of the method used in these studies, since the writer has already pointed out (8, 9) some of its irrational features and further discussion will be made elsewhere. Suffice it to say that after considerable study and investigation the writer believes that certain features of this method, especially the concentration of the nitrogenous substances employed, are so abnormal as to cast serious doubt on the practical value of the data obtained.

At any rate, it is a matter of interest to note that under the conditions employed in the experiments referred to above, magnesium carbonate was found to be notably toxic to nitrification in certain soils and only slightly so in others. Calcium carbonate, on the other hand, was stimulating in certain soils and produced only slight effects in others. In regard to ammonification, magnesium carbonate was again found to be toxic when added to certain sandy or silty types of soil, but stimulating in the heavier types of soil where calcium carbonate produced only slight effects.

In no case did the further addition of calcium carbonate greatly modify the effects produced by magnesium carbonate alone. In contrast to the effects of precipitated magnesium carbonate, the naturally occurring double carbonate of magnesium and calcium, dolomite, was found to produce effects similar in every way to that of calcium carbonate, and was not toxic in any case, even in soils where precipitated magnesium carbonate was extremely toxic. In one soil, for example, with all other conditions the same, it was found that nitric nitrogen was formed at the rate of 670 p.p.m. where calcium carbonate was added, 700 p.p.m. where dolomite was added, and only 38 p.p.m. where the same percentage (2 percent) of precipitated magnesium carbonate was added. In another case, the addition of only 0.1 percent precipitated magnesium carbonate to a sandy type of soil from California almost completely suppressed the formation of nitrate, while the addition of calcium carbonate in quantities up to 8 percent produced notable stimulation.

In discussing these data (6, 7) the writer made some reference to the possibility of excessive alkalinity having been a limiting factor where precipitated magnesium carbonate was used, but, on the whole, the view was expressed that the concentration of magnesium in the soil moisture was probably the more important factor. It was suggested that the concentration of magnesium in solution in soils might possibly become too high in certain cases for the progress of suitable biochemical action. But the results were interpreted as indicating that the ratio of calcium to magnesium is without significance so far as nitrification and ammonification are concerned. In the light of data presented below, however, it now seems more probable that the extreme toxicity produced by precipitated magnesium carbonate was due to excessive alkalinity.

Lipman and Burgess (13) have more recently studied the effects of magnesium carbonate on nitrogen fixation by pure cultures of *Azotobacter chroococcum* and have found it to be distinctly toxic when added in more than very low concentrations. They likewise interpreted their results as being not due to excessive alkalinity but rather to excessive concentration of magnesium brought about by the treatment.

In the course of some recent studies on the effects of various substances on nitrification, data have been obtained which are of interest in this connection.

## Experimental Results.

The experiments were made with the use of two light sandy loam soils low in organic matter, drawn near Riverside, Cal. Varying amounts of different substances (Baker's analyzed chemicals) were mixed with 100-gram portions of air-dried soil. After adjusting the moisture and incubating at 25° C. for four weeks, the nitrate was determined by the phenol-disulphonic acid method. In Table 1 are given the results showing the comparative effects of magnesium sulfate and magnesium carbonate on the nitrification of ammonium sulfate. The experiments were made in duplicate with closely agreeing results.

These data are in harmony with the results previously reported in showing that the addition of the precipitated magnesium carbonate may interfere with the formation of nitrate to a marked degree. As small an amount as 0.05 percent magnesium carbonate reduced the yield of nitrate in one soil from 84 p.p.m. to 70 p.p.m., and in another from 170 p.p.m. to 124 p.p.m., while the higher percentages produced still more marked effects. Almost the same effects were pro-

duced by 0.1 percent as by 0.5 percent in each soil. This may be explainable by the fact that, since magnesium carbonate is a difficultly soluble substance, either of these amounts was sufficient to produce a saturated solution in the soil moisture. If so, the same effects might reasonably be expected to be produced in each case.

On the other hand, the addition of magnesium sulfate up to as much as 0.5 percent produced no effect on nitrate formation. The effects of precipitated magnesium carbonate and magnesium sulfate, therefore, were widely different.

TABLE 1.—*Comparative effects of magnesium carbonate and magnesium sulfate on nitrification.*

| Materials added. | Parts per million of nitric nitrogen. | |
|---|---|---|
| | Soil No. 1. | Soil No. 2. |
| None | 10.0 | 34.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ | 84.0 | 170.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $MgCO_3$ | 70.0 | 124.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $MgCO_3$ | 17.0 | 47.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $MgCO_3$ | 13.2 | 44.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $MgSO_4$ | 82.5 | |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $MgSO_4$ | 83.5 | |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $MgSO_4$ | 82.0 | |
| Original soil | 1.2 | 5.0 |

It has been pointed out elsewhere (5, 9) that precipitated magnesium carbonate may interfere with the formation of nitrate without being toxic to the formation of nitrite. In 1915 Pañganiban (16) also noted this fact in some studies on soils from the Philippine Islands. Since nitrite becomes reduced to ammonia under the influence of the reducing agents employed in the several reduction methods that are in use for the determination of nitrate, it is evident that the amounts of nitrogen found by these methods should not be looked upon as being derived solely from nitrate unless actual test proves the absence of nitrite.

The above results would seem to indicate that the marked effects of precipitated magnesium carbonate on nitrification previously noted were not so much due to modifications in the lime-magnesia ratio or to increases in the concentration of magnesium as to effects on the reaction of the soil.

In further study of this subject, a considerable range of substances was used in order to obtain evidence regarding the importance of an interchange of bases as a factor of influence. Soil No. 1 was used, with the same concentration of ammonium sulfate as in the preceding series. The results are shown in Table 2.

TABLE 2.—*Comparative effects of different substances on nitrification.*

| Materials added. | Nitric nitrogen, p.p.m. |
|---|---|
| None | 10.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ | 89.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $Na_2CO_3$ | 56.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $Na_2CO_3$ | 33.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $Na_2CO_3$ | 1.1 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $Na_2SO_4$ | 76.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $Na_2SO_4$ | 60.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $Na_2SO_4$ | 41.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $K_2CO_3$ | 30.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $K_2CO_3$ | 17.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $K_2CO_3$ | 2.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $K_2SO_4$ | 83.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $K_2SO_4$ | 83.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $K_2SO_4$ | 52.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent CaO | 15.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent CaO | 6.6 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent CaO | 0.8 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $CaSO_4$ | 84.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $CaSO_4$ | 87.5 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $CaSO_4$ | 84.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $MgCO_3$ | 57.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $MgCO_3$ | 17.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $MgCO_3$ | 16.4 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.05 percent $MgSO_4$ | 82.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.10 percent $MgSO_4$ | 85.0 |
| 0.15 percent $(NH_4OH)_2SO_4$ and 0.50 percent $MgSO_4$ | 80.0 |

The results shown in Table 2 indicate again that the depressing effect of precipitated magnesium carbonate on nitrification is due to the fact that this substance may produce excessive alkalinity in soils. It is shown, for example, that both sodium carbonate and potassium carbonate produced effects quite similar to magnesium carbonate, while calcium oxide was somewhat more toxic than either of these substances. In view of the fact that calcium hydrate is known to be more strongly basic than magnesium carbonate, the results obtained from the use of calcium oxide may be interpreted as supporting the view that the toxicity of precipitated magnesium carbonate was due to injurious alkalinity.

The results of the application of different sulfates also indicate that the differences in the effects produced by magnesium sulfate and magnesium carbonate can hardly be attributed to an interchange of bases in the soil.

These data are also of interest in relation to the lime-magnesia

ratio. The effects of increasing amounts of calcium sulfate were almost identical with those of magnesium sulfate, neither having produced any notable effect. As will be shown elsewhere, magnesium sulfate has the power of replacing small amounts of calcium from this soil, but only limited amounts. Chemical studies on this soil afford the proof that the ratio of calcium to magnesium in solution resulting from the application of calcium sulfate and magnesium sulfate must necessarily have been markedly altered by the amounts used above. Nevertheless, almost no effects were produced on the nitrification of ammonium sulfate. The conclusion seems warranted, therefore, that the nitrifying organisms have the power of adapting themselves to and can function equally well in the presence of considerable variations in the lime-magnesia ratio.

The writer has pointed out elsewhere (9) that the effects of certain soluble substances on the formation of nitrates differ widely when different concentrations of nitrogenous substances are employed. For example, with the use of 1 percent dried blood in one soil, 0.05 percent sodium carbonate caused a diminution in the yield of nitrate from 172 p.p.m. to 31 p.p.m., while as much as 0.4 percent sodium carbonate produced no effect on the nitrification of 0.1 percent dried blood. Likewise, in another soil, when 0.15 percent ammonium sulfate was used, the addition of 0.1 percent sodium carbonate diminished the yield of nitric nitrogen from 89 p.p.m. to 33.5 p.p.m. while marked stimulation resulted from the addition of the same amount of sodium carbonate when 0.0625 percent ammonium sulfate was used. Similar results have been obtained with the use of precipitated magnesium carbonate, as are shown in Table 3.

TABLE 3.—*The effects of magnesium carbonate on the nitrification of different concentrations of dried blood.*[a]

| Material added. | Parts per million of nitric nitrogen. | |
|---|---|---|
| | 1.0 percent dried blood. | 0.10 percent dried blood. |
| None | 172.0 | 106.0 |
| 0.05 percent $MgCO_3$ | 192.0 | |
| 0.10 percent $MgCO_3$ | 88.0 | 102.0 |
| 0.50 percent $MgCO_3$ | 40.0 | 104.0 |

[a] Soil No. 2.

These data show that marked diminution in the yield of nitrates from 1 percent dried blood resulted from the use of both 0.1 percent and 0.5 percent magnesium carbonate, while no effects were noted on the nitrification of 0.1 percent dried blood.

It is highly probable that the alkalinity due to the ammonia formed from 1 percent dried blood became so high as to approach the toxic limit, in consequence of which only slight amounts of any other alkaline substance (magnesium carbonate) were required to effect prohibitive concentrations of alkalinity.

## Discussion.

The preceding data show quite clearly that the effects produced by precipitated magnesium carbonate may differ widely from those of magnesium sulfate. The addition of comparatively small amounts of the former retarded the formation of nitrate to a marked degree, while as much as 0.5 percent of the latter produced no effect. It was also shown that the addition of other alkaline reacting substances such as sodium and potassium carbonates and calcium oxide produced effects similar to magnesium carbonate. In view of the fact that magnesium sulfate produced no effect on the nitrifying process and that precipitated magnesium carbonate and dolomite have previously been found to produce widely different effects, the former being toxic and the latter stimulating, and since much of the ordinary precipitated magnesium carbonate is known to contain magnesium hydrate, the conclusion would seem to be justified that the toxic effects that have frequently been noted in studies with the use of this material have been occasioned by excessive alkalinity. The writer recognizes, however, that it will be necessary to show that the toxicity of precipitated magnesium carbonate is positively correlated with the hydroxyl ion concentration before the above conclusion can be definitely drawn. Investigations are being made with this end in view.

In any event, the data submitted above justify the conclusion that the inhibiting influence of precipitated magnesium carbonate toward nitrification was not due simply to excessive concentrations of the magnesium ion, for there can be little doubt that the larger amounts of magnesium sulfate produced considerably higher concentrations in the soil moisture than did the magnesium carbonate.

In connection with the investigations of Lipman and Burgess (13) on the effects of magnesium carbonate on introgen fixation, referred to above, they sought to determine whether alkalinity was an important factor. The method used consisted first in determining the degree of alkalinity of a saturated solution of the magnesium carbonate and then in studying the nitrogen-fixing power of Azotobacter in Ashby's mannite nutrient solution to which sufficient potassium hydrate had been added to effect a degree of alkalinity corresponding to that of a saturated solution of magnesium carbonate. They found,

however, that nitrogen fixation was stimulated by the addition of the potassium hydrate. Consequently the conclusion was drawn that the toxicity of magnesium carbonate was not due to injurious alkalinity, but to the magnesium ion. They say:

> The causticity of chemically pure magnesium carbonate as prepared by the Baker Chemical Company does not account for the toxic effects of magnesium carbonate. The latter effects must be due to the magnesium ion. The alkalinity of magnesium carbonate is beneficial, rather than otherwise, to *A. chroococcum*.

Careful study of the conditions that ensued in the experiments of Lipman and Burgess will show, however, that the effects noted may still be interpreted as having been due in part, at least, to excessive alkalinity. For, upon the addition of potassium hydrate to a portion of Ashby's mannite solution, it is probable that slight precipitation of calcium and magnesium phosphates took place, thus introducing the solid phase, the absorptive power of which may have been a factor. But what is more important, the organic compounds that were probably formed as a result of the decomposition of the mannite may have combined with the potassium hydrate and thus lowered the alkalinity.

Where magnesium carbonate was used, the smallest amount was in excess of that capable of being completely dissolved in the solution present. Consequently, potential alkalinity was present throughout the experiment in sufficient amounts to maintain a saturated solution, whereas the mannite solution containing potassium hydrate probably became less and less alkaline as the growth of the organisms proceeded.

It should also be mentioned that Ashby (1) found magnesium carbonate to produce greater stimulation in nitrogen fixation by Azotobacter in mixed cultures than calcium carbonate, and in each case a greater amount was fixed than in neutral solutions. A full explanation of the discrepancy in his results, as compared with those of Lipman and Burgess, can not be given. It is possible, however, that the magnesium carbonate which he used contained less magnesium hydrate than that used by Lipman and Burgess, and also that the activity of other organisms present tended to neutralize the magnesium carbonate. Ashby calls attention to the fact that butyric odors were produced in his neutral cultures, but not where magnesium carbonate was used. In commenting on this point, he says:

> During concentration the neutral cultures developed a strongly acid odour, those with calcium carbonate a weaker one, and those with magnesium carbonate, alone or mixed with calcium carbonate, gave no odour. When mag-

nesium carbonate was present, development was greatly delayed, but the yield of nitrogen was again larger, though not to so marked an extent as in the earlier experiment. In pure culture, *Azotobacter* gives rise to no acidity, either in solutions or on agar. One must conclude, therefore, that magnesium carbonate not only neutralizes more effectually than calcium carbonate any trace of acidity due to foreign organisms in the early stages of culture, but also prevents butyric fermentation, but at first it inhibits the growth of *Azotobacter* itself.

Finally, the investigations of McIntyre (14) afford strong evidence that precipitated magnesium carbonate is capable of exerting a strongly basic reaction in soils, as is shown by the fact that very large amounts of it were found to undergo decomposition with the evolution of carbon dioxide over long periods of time.

In view of the fact that the naturally occurring carbonates of magnesium produce widely different effects from the precipitated carbonate, together with the evidence set forth above, it seems reasonable to conclude that this material is unsuited for studies on the lime-magnesia ratio. With its use, effects on the reaction of the soil may so affect physiological processes as to obscure the effects that may be inherent within the ratio of calcium to magnesium itself, and therefore the result obtained may lead to entirely erroneous conclusions.

The data recorded above suggest the importance of the most thorough understanding of the chemical factors induced in soils by the application of treatments of different sorts. Soils are made up of complex yet varying mixtures of many substances, both organic and inorganic, the essential nature of some of which is known and of others little is definitely known. There is much evidence that the several points of chemical equilibrium in soils are easily shifted by the application of various substances, and the effects that finally manifest themselves on the physiological behavior of either the microorganisms or of the higher plants may or may not be due to the direct action of the substance applied.

Furthermore it is quite possible that the effects observed on the microbiological phenomena of soils do not bear a necessarily direct relation to the growth of crops. The urgent need in this as in other phases of soils and crop production is for exact knowledge concerning the chemistry and physics involved, without which the interpretation of soil biological phenomena must remain speculative.

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# EXCESS SOLUBLE SALTS IN HUMID SOILS.[1]

S. D. CONNER.[2]

When any soil in Indiana or the adjoining States in fair physical condition fails to produce good crops the usual procedure is to try to find what is lacking, so that lime, organic matter, or some fertilizing element may be supplied in order that better crops may be grown. While most soil troubles of a chemical nature in humid regions are due to lack of some necessary ingredient, there are some cases where the trouble is due to an excess of one or more soluble salts. The injury caused by these soluble salts may be due in some cases to toxic action of more or less dilute solutions of certain salts or it may be due to plasmolysis caused by relatively concentrated solutions of salts that are otherwise not injurious.

The occurrence of excessive amounts of soluble salts in soils of humid regions has been reported by Cameron[3] as occurring in Maryland, Florida, etc. The Soils and Crops Department of the Indiana Agricultural Experiment Station[4] has reported unproductive soils which contained excessively high nitrate and other soluble salts. Stevenson and Brown[5] have also noted such soils as occurring in Iowa. Ames and Schollenberger[6] report Ohio soils containing large percentages of soluble salts.

The following cases relate to humid soils containing rather concentrated salt solutions. In September, 1913, two samples of peat soil were received from a farm near Toto, Starke Co., Ind. The

[1] Contribution from Soils and Crops Department, Indiana Agricultural Experiment Station. Received for publication March 29, 1917.

[2] The writer desires to acknowledge the assistance of Mr. H. R. Smalley, who performed some of the analytical work presented in this paper.

[3] Cameron, F. K. Soil solutions. U. S. Dept. Agr., Bur. Soils Bul. 17, p. 36. 1901.

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[5] Stevenson, W. H., and Brown, P. E. Iowa peat and alkali soils. Iowa Agr. Expt. Sta. Bul. 157. 1915.

[6] Ames, J. W., and Schollenberger, C. J. Accumulations of salts in Ohio soil. *In* Soil Science, vol. 1, no. 6, p. 575. 1916.

soil from a part of the field where onions were doing well contained 0.45 percent soluble salts with 0.10 percent $NO_3$. The sample from a part of the field where onions were dying contained 1.2 percent soluble salts with 0.44 percent $NO_3$. One week later samples from another part of the same field were taken at depths of 1 inch, 6 inches, and 18 inches. The determinations of soluble salts and of nitrates are given in Table 1.

TABLE 1.—*Percentages of soluble salts and of nitrates at different depths from two samples of peat soil from an onion field in Starke Co., Ind.*

| Depth of soil sample. | Onions good. | | Onions poor. | |
|---|---|---|---|---|
| | Soluble salts. | $NO_3$. | Soluble salts. | $NO_3$. |
| 0 to 1 inch.......... | 0.22 | 0.100 | 0.52 | 0.3400 |
| 1 to 6 inches......... | .13 | .045 | .22 | .0600 |
| 6 to 18 inches........ | .11 | .060 | .14 | .0025 |

Samples taken in July, 1916, near Cromwell, Ind., on peat soil contained 1.12 percent of soluble salts and 0.50 percent $NO_3$ where the onions were doing poorly and 0.57 percent of soluble salts and 0.17 percent $NO_3$ where the onions were still good. In a number of other instances where onions were doing poorly on peat soils high percentages of soluble salts have been found.

The analyses of four unproductive black soils are given in Table 2 and the composition of water extracts of the same soils is shown in Table 3. These four soils may be described as follows:

A. Unproductive peat from Noble Co. This soil failed to produce corn or onions after fertilization with potash and phosphate.

B. Unproductive peat from Starke Co. on which onions failed to grow after potash and phosphate fertilization.

C. Unproductive peat from Kosciusko Co. This soil had never produced a crop before or after fertilization.

D. Unproductive peaty sand from Wanatah Field in Laporte Co., Ind. Crops did not grow on this soil until 2 tons to the acre or more of limestone, together with acid phosphate and potash, were applied. Good crops were produced after this treatment.

Soils A and B are of a type similar to the Toto and Cromwell soils where at certain seasons of the year the concentration of salts at the surface may be easily high enough to plasmolyze the tissue of tender growing plants. These soils are often coated with a white crust and may be truly called alkali soils. The composition of the water extract as shown in Table 3 would indicate that the bulk of the alkali salts are nitrates with lesser amounts of sulfates and chlorids. Calcium is the most abundant base. While these soils are

TABLE 2.—*Analyses of four unproductive black soils in Indiana.*

| Determination. | Soil A. | Soil B. | Soil C. | Soil D. |
|---|---|---|---|---|
| | *Percent.* | *Percent.* | *Percent.* | *Percent.* |
| Insoluble $SiO_2$, etc.[a] | 8.96 | 5.65 | 14.71 | 88.63 |
| $K_2O$ | .17 | .20 | .12 | .14 |
| $Na_2O$ | .14 | .18 | .06 | .05 |
| $CaO$ | 3.32 | 2.99 | .03 | .08 |
| $MgO$ | .43 | .52 | .24 | .11 |
| $Mn_3O_4$ | Trace | Trace | Trace | Trace |
| $Fe_2O_3$ | .72 | .78 | .24 | .78 |
| $Al_2O_3$ | 3.75 | 1.28 | 1.03 | 2.64 |
| $P_2O_5$ | .50 | .36 | .25 | .08 |
| $SO_3$ | .56 | .66 | .21 | .10 |
| $CO_2$ | .32 | Trace | Trace | Trace |
| Volatile | 79.41 | 87.72 | 83.53 | 8.16 |
| Total humus | 33.58 pct. | 31.09 pct. | 44.45 pct. | 4.86 pct. |
| Acid humus[b] | 10.06 pct. | 16.64 pct. | 43.08 pct. | 4.64 pct. |
| Total nitrogen | 3.57 pct. | 4.03 pct. | 2.34 pct. | .28 pct. |
| Nitrates ($NO_3$)[c] | 1,000 ppm. | 2,670 ppm. | 167 ppm. | 134 ppm. |
| Acidity[d] | 250 lbs. | 750 lbs. | 8,000 lbs. | 3,500 lbs. |

[a] Digestion in HCL, sp. gr. 1.115.
[b] Extracted without previous acid treatment.
[c] Phenol di-sulfonic acid method.
[d] Potassium nitrate method. Results expressed in pounds of $CaCO_3$ per 2,000,000 pounds of soil.

somewhat acid in reaction, they contain a large amount of calcium and organic nitrogen. During the warm weather of spring and summer, active nitrification sets in and large amounts of nitrates accumulate. These nitrates, together with other soluble matter, are brought to the surface and are deposited when the soil moisture evaporates. This type of soil gives no trouble and shows no exces-

TABLE 3.—*Composition of the water extract from the four unproductive black soils, the analyses of which are given in Table 2.*

| Determination. | Soil A. | Soil B. | Soil C. | Soil D. |
|---|---|---|---|---|
| | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| $SiO_2$ | [a]0.0720 | 0.0312 | 0.0078 | 0.0161 |
| K | .0456 | .1080 | .0321 | .0118 |
| Na | .0393 | .0737 | .0158 | .0342 |
| Ca | .2070 | .6066 | .0113 | .0200 |
| Mg | .0335 | .1573 | .0072 | .0202 |
| Fe | .0000 | .0002 | .0000 | .0010 |
| Al | .0025 | .0270 | .0155 | .0172 |
| $NH_4$ | .0053 | .0208 | .0667 | .0062 |
| $PO_4$ | .0044 | .0145 | .0103 | .0080 |
| $SO_4$ | .1543 | .3567 | .0855 | .0177 |
| $NO_3$ | .7407 | 2.6667 | .1066 | .2500 |
| Cl | .1332 | .3000 | .0613 | .0693 |
| Organic matter, etc. | .1762 | .3040 | .5482 | .1577 |

[a] Grams dissolved by leaching one kilo of soil with 4,000 cc. distilled water.

sive accumulation of salts when left in grass and not cultivated. Trampling by stock as in pasturing has a tendency to benefit them permanently. Rolling with very heavy power rollers has been tried with more or less success. The more compact they are kept the less active is the nitrification and the less the salts tend to accumulate.

Soils C and D are types found in some localities in Indiana. Such soils are quite low in calcium or other bases and are very acid. The water extracts show relatively high concentrations of aluminum salts which have been shown to be quite toxic to plant roots in very dilute solutions. This type of soil does not show very high concentrations of total salts. There appears to be little doubt that the unproductiveness of this type of soil is due principally to the presence of soluble aluminum salts.[7] All very acid black soils which have been examined by the writer have been found to contain water soluble salts of aluminum. In some black soils doubtless the infertility may be due to a combination of high soluble salts and to toxic substances.

There are also large tracts of peat and peaty sand soils in Indiana which do not come in either class of the soils which have been discussed. Probably the largest areas of peaty and muck soils in this State are deficient in potash. There are other areas which respond only to phosphate.[8]

Other than the black soils, there are probably no alkali soils of natural origin in Indiana. Quite often, however, some land owner sends to the experiment station a sample of soil which will not produce crops on account of too much soluble salts. Such soils are generally of artificial origin caused by accumulation of refuse. A farmer near Warren, Ind., reported a spot of soil in a field on which nothing would grow. The percentages of water-soluble materials found in samples of this soil taken at depths of 0–6, 12–18, and 24–30 inches are shown in Table 4.

TABLE 4.—*Water-soluble materials in silt loam soil from unproductive spot near Warren, Ind.*

| Determination. | Depth of sample. | | |
|---|---|---|---|
| | 0–6 inches. | 12–18 inches. | 24–30 inches. |
| | *Percent.* | *Percent.* | *Percent.* |
| Nitrates ($NO_3$) | 0.10 | .03 | 0.012 |
| Potash ($K_2O$) | .85 | .42 | .440 |
| Soluble salts | 2.54 | 1.40 | 1.330 |

[7] Abbott, J. B., Conner, S. D., and Smalley, H. R. The reclamation of an unproductive soil of the Kankakee marsh region. Ind. Agr. Expt. Sta. Bul. 170. 1913.

[8] Conner, S. D., and Abbott, J. B. Unproductive black soils. Ind. Agr. Expt. Sta. Bul. 157. 1912.

The analysis in Table 4 shows that the unproductivity was due to the presence of water-soluble salts, principally potash. This unproductive place was in a part of the field where a stable had been located up to five years previous. This is a good demonstration of the fact that plant food is being continually lost by leaching in stables that do not have water-tight floors. In this case the farmer was advised to dig out the unproductive spot and spread it on the remainder of the field as manure. Similar soils from other parts of the State have been tested with like results.

### Summary.

1. Black soils in humid regions sometimes contain excessive amounts of soluble salts.

2. These soluble salts may cause injury to crops, due to high concentration of nontoxic salts, to a lower concentration of more toxic substances, or to a combination of both.

3. The salts occurring in high concentration are generally nitrates.

4. The toxic salts occur generally in acid soils and are mainly soluble salts of aluminum.

5. The only clay and loam soils that were found to contain excessive soluble salts were of artificial origin, such as spots where old stables had stood.

Indiana Agr. Expt. Station,
La Fayette, Indiana.

# AGRONOMIC AFFAIRS.

## THE ANNUAL MEETING.

The Executive Committee of the American Society of Agronomy, at a meeting last November, agreed to hold the next meeting at the same place as and on the two days preceding the meeting of the Association of American Agricultural Colleges and Experiment Stations. At that time it was the plan of the latter organization to meet in Springfield, Mass., in October, in connection with the semicentennial celebration of the Massachusetts Agricultural College. This celebration has been abandoned and the Executive Committee of the A. A. A. C. E. S. has decided to meet in Washington, D. C., about the middle of November. The tenth annual meeting of the American Society of Agronomy will be held, therefore, in Washington, presumably on November 12 and 13. All those who expect to attend and to present papers are requested to send titles to the Secretary at the earliest possible date. Also, those who plan to come are asked to inform the Secretary as to whether or not they will attend an agronomists' dinner on Monday, November 12, if one is arranged.

## MEMBERSHIP CHANGES.

The membership of the Society, as reported in the May issue, was 643. Since that time 9 new members have been added, 4 have been reinstated, and 1 has resigned, a net gain of 12 and a present total membership of 655. The names and addresses of the new and reinstated members and the name of the member who has resigned, with such changes of address as have come to the notice of the Secretary, are as follows:

### New Members.

Daane, Adrian, 225 Duncan St., Stillwater, Okla.
Fleming, Frank L., Jireh, Wyo.
Graham, E. E., R. No. 2, Stonewall, Okla.
Jarvis, Orin W., Pacific Sugar Corporation, Tracy, Cal.
Kime, P. H., West Raleigh, N. C.
Murphy, Henry, 318 West St., Stillwater, Okla.
Riley, J. A., Chester, S. C.
Spencer, E. L., 210 Elm St., Stillwater, Okla.
Ware, J. O., West Raleigh, N. C.

### Members Reinstated.

Chapman, James E., 2316 Pierce Ave., St. Anthony Park, St. Paul, Minn.
Currey, Hiram M., Bureau of Markets, U. S. Dept. Agr., Washington, D. C.
Lechner, H. J., Washington State Normal School, Ellensburg, Wash.
Wilson, Bruce S., Experiment Station, Manhattan, Kans.

### Member Resigned.

Peters, David C.

### Addresses Changed.

Barker, Joseph F., College of Agriculture, Columbus, Ohio.
Boving, Paul A., University of British Columbia, Vancouver, B. C.
Burnett, Grover, Mackay, Idaho.
Currey, Hiram M., Bureau of Markets, U. S. Dept. Agr., Washington, D. C.
Dorsey, Henry, Agr. Expt. Sta., Morgantown, W. Va.
Fletcher, O. S., E. 915 Augusta Ave., Spokane, Wash.
Hendry, Geo. W., University of California, Berkeley, Cal.
Hill, Pope R., 215 Lucy Ave., Memphis, Tenn.
Hodson, Edgar A., Box 285, West Raleigh, N. C.
Holland, B. B., 800 Jefferson St., Amarillo, Tex.
Hulbert, Harold W., Farm Crops Dept., University of Idaho, Moscow, Idaho.
Hutchison, C. B., Dept. Plant Breeding, Cornell Univ., Ithaca, N. Y.
McAdams, James, care State Board of Agr., Topeka, Kans.
Miller, Frank R., Room 2132, 2 Rector St., New York, N. Y.
Miyake, Kōji, College of Agr., Tohoku Imp. Univ., Sapporo, Japan.
Schick, G. M., Plainview, Tex.
Olson, M. E., Soils Section, Iowa State College, Ames, Iowa.
Sleeth, E. C., Jefferson, Ohio.
Van Evera, R., Abraham, Utah.
Smith, Raymond S., 304 Elmwood Ave., Ithaca, N. Y.
Taggart, J. G., Lower Onslow, Nova Scotia, Canada.

## NOTES AND NEWS.

H. W. Barre has been appointed director of research at Clemson College, S. C. He will be director of the experiment station but not dean of the college; the latter office will not be filled at present.

N. Eric Bell, formerly with the Alabama State soil survey, is now county agent in Hale Co., Ala., with headquarters at Greensboro.

Sidney Bliss of Ohio State University has been appointed assistant in the division of soils at the Ohio station.

W. C. Boardman and O. H. Smith, assistants in the soil survey at the Ohio station, have resigned.

P. A. Boving, who has been in charge of root investigations at Macdonald College, is now assistant professor of agronomy in the University of British Columbia.

A. D. Hall, formerly director of the Rothamsted station and well-known writer of agricultural books, has been appointed permanent secretary of the Board of Agriculture and Fisheries of Great Britain.

J. G. Hamilton, assistant agronomist of the New Mexico station, resigned March 1 to become county agent of Valencia Co., N. Mex.

E. C. Higbie, superintendent of the West Central School of Agriculture and of the substation at Morris, Minn., has resigned, effective July 31.

H. W. Hulbert, a graduate of the Michigan college and post-graduate of the Iowa college (1917), has been appointed to the farm crops department of the University of Idaho.

Dr. George E. Ladd has resigned as president of the New Mexico college and has been succeeded by Dr. A. D. Crile.

C. E. Neff is assistant in agronomy at the Delaware college and station.

M. E. Olson, scientific assistant in corn investigations in the U. S. Dept. of Agriculture for the past year, has returned to the Iowa college, where he will superintend cooperative experiments in soil fertility over the State.

George Severance, formerly professor of agriculture of the Washington college, is acting director of the Washington station, succeeding Ira D. Cardiff.

V. M. Shoesmith, professor of farm crops and farm crops experimentalist at the Michigan station since 1910, is now superintendent of a 4,300-acre tract of land near Grand Rapids, Mich.

R. R. Spafford is now assistant in farm management at the Nebraska station.

A section of the American Society of Agronomy has been established at the University of Illinois, with Robert Stewart president, E. A. White, vice-president, and E. A. Torgerson, secretary-treasurer.

The State of Texas has recently located junior agricultural colleges at Stephenville and Arlington. At Stephenville the buildings and grounds of John Tarleton college have been acquired and 500 acres of land donated for experimental and demonstration purposes. A locating board has also inspected numerous sites with a view to locating the new West Texas Agricultural and Mechanical College.

# JOURNAL

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## THE EFFECT OF PROLONGED GROWING OF ALFALFA ON THE NITROGEN CONTENT OF THE SOIL.[1]

C. O. SWANSON.

Grain crops get their nitrogen from the soil. The ultimate source of this nitrogen is the air. Over each acre there is enough nitrogen to produce 50,000,000 bushels of corn. All crops get their carbon from the air. Over each acre there is only enough carbon to produce 200 bushels, yet carbon has never figured in the commercial valuation of plant food, while under normal conditions nitrogen is the most expensive element. (Abnormal conditions due to the great war make potassium at present the most expensive.) The fundamental reason for this difference between nitrogen and carbon is that all green plants have their own physiological organ for obtaining carbon from the air, while they have no such corresponding organ for obtaining nitrogen. Thus, while plants are bathed in an atmosphere approximately four fifths nitrogen, they starve for the want of it unless they can get it from the soil. On the other hand, they get all the carbon they need, although the atmosphere contains only about 0.01 percent.

The power of legumes to improve the crop-producing power of the soil was known to the ancients. Just how this improvement came about remained for the modern chemist and bacteriologist to demonstrate. The scientific facts connected with these phenomena are so well known that it is not necessary to dwell on them here, but, like all new discoveries, certain phases are likely to be overworked. Stu-

[1] Contribution from the Department of Chemistry of the Kansas Agricultural Experiment Station, Manhattan, Kans. Read at the spring meeting of the American Chemical Society, Kansas City, Mo., April, 1917. This is a partial report of work still in progress. Received for publication May 10, 1917.

dents of soil fertility who have studied deeply and who think clearly have questioned some of the enthusiastic statements made in regard to the power of legumes to restore and maintain the crop-producing power of the soil.

No attempt is made in this paper to review the literature on the subject. From experimental work under scientific control as well as from the practical experience of farmers, there is abundant evidence as to the power of legumes to improve the crop-producing power of the soil. The only question of which there is any doubt is in regard to the amount of nitrogen added to the soil when legumes are grown under conditions usually found on the American farm. As compared with other legumes, particularly red clover, little work has been done with alfalfa. This is partly due to the fact that alfalfa has not been grown generally by farmers in this country for as long a time as red clover, and partly to the fact that alfalfa is not so readily adapted to rotations. When a field has a good stand of alfalfa the value of this crop is so great that it is often more profitable to continue growing it there than to plow it under and grow something else.

A few citations from reports of work on this phase of soil fertility illustrate the general situation. Knorr[2] makes the following statement: "In every case where crop followed alfalfa the highest average yields were obtained, indicating very strongly that the alfalfa has a beneficial effect on the succeeding crop." This is a usual conclusion from experiments of this nature and such results are entirely possible without the actual increase in the stock of nitrogen in the soil. Lyon and Bizzell[3] grew alfalfa and timothy for six years on adjoining plots. On plowing up these were planted to corn the first year and to oats the second. The yield of corn grain was 62 bushels on the alfalfa plot and 47 on the timothy plot. The oats yielded 26 bushels on the alfalfa and 27 on the timothy plot. Analysis of the soils from the two plots showed that the alfalfa soil contained not to exceed 0.01 percent more nitrogen than the timothy soil. This would amount to 250 pounds per acre if the soil is assumed to weigh 2,500,000 pounds to a depth of 8 inches, Anyone who has sampled and analyzed soil knows the difficulty of working on such a small margin. This work of Lyon and Bizzell raises the two questions of most importance in connection with the relation of legumes to soil fertility: (1) Was there a greater accumulation of nitrogen in the

[2] Knorr, F. U. S. Dept. Agr., Bur. Plant Ind., Rept. of work on Scottsbluff experiment farm, 1913.

[3] Lyon, T. L., and Bizzell, J. A. Experiments concerning the top-dressing of timothy and alfalfa. N. Y. Cornell Agr. Expt. Sta. Bul. 339. 1913.

alfalfa soil during the six years than there was in the timothy soil during the same length of time? (2) Was the greater productivity of the alfalfa soil due to the greater availability of the nitrogen?

Alway and Bishop[4] report analyses of samples of soil from an alfalfa field and from a corn field. They conclude that "no marked difference is to be seen between the amounts of nitrogen in the soil of the two fields as represented by the samples analyzed."

This paper does not deal with the question of whether the stock of nitrogen in the soil can be increased through the growing of legumes (in this case, alfalfa). The question is: When alfalfa has been grown on land for a number of years and all the crop has been harvested as hay, no return of any kind having been made to the soil, has the stock of nitrogen been increased on that particular piece of land?

To find out what prolonged growing of alfalfa does to the soil was a question taken up by the Kansas Agricultural Experiment Station two years ago. A number of fields in Kansas have been continuously in alfalfa for twenty to thirty years or more. In most cases it is possible to find near by soil of the same type which has been continuously under cultivation since it was broken, thirty-five or forty years ago, and soil in native sod, used either as pasture or as hay land. By sampling and analyzing the soil in the various fields it is possible to learn something in regard to the effect of long production of alfalfa on the soil. This experiment was carried on in cooperation between the departments of chemistry and agronomy. The samples have all been taken by the author, either alone or with the assistance of field members of the Division of Extension.[5]

The samples were generally taken in four different strata, namely: 0–7 inches; 7–20 inches; 20–40 inches; and 40–80 inches. For the upper three strata a soil auger was generally used. For the lowest it was found best to use a soil tube, particularly in western Kansas. Borings were made in a number of places in the field sampled. In most cases the alfalfa field, the field in native sod, and the field under continuous cultivation were in very close proximity, separated only by a fence or a road. In western Kansas most of these fields were on bottom soil. Anyone who has sampled soil for chemical analysis knows that bottom soils are most difficult to sample because of the

[4] Alway, F. J., and Bishop, E. S. Some notes on the alfalfa and clover residues as sources of soil nitrogen. *In* 25th Ann. Rpt. Nebr. Agr. Expt. Sta., p. 56–65. 1911.

[5] To all who have assisted in this work the author wishes to express his appreciation, particularly to Mr. W. L. Latshaw, who is in charge of the chemical soil laboratory.

abrupt changes that are found, especially in strata below the surface. Because of this difficulty the results of analysis do not always show the correlation expected. In this paper results on nitrogen only are presented. The samples were analyzed also for phosphorus, calcium, and carbon, the latter in order to obtain data on the amount of organic matter.

The results of the chemical analysis for nitrogen are given in Table 1. This table gives the county where the sample was obtained, the sample number, the cropping condition of the field, and the percentages of nitrogen found in the four different strata. In making a preliminary study of these figures it was found that the results could be classified under three heads, viz: samples taken in the eastern portion of the state, where the rainfall is about 30 inches or more; samples taken in the west central part, where the rainfall is less than 30 but more than 20 inches, and samples taken west of the line of 20-inch rainfall. These regions will be referred to as humid, semihumid, and semiarid.

One of the first facts noticed is that in the semiarid portions of the state the alfalfa soils have at least as high a percentage of nitrogen as the soils in native sod and that the difference between the cultivated soils and the soils in native sod is small. In humid regions all the soils in native sod contain a larger percentage of nitrogen than the soils in alfalfa, while with a few exceptions the soils in alfalfa contain a larger percentage of nitrogen than those continuously cropped. It should be noted that the alfalfa fields in the humid section were on the average less than two thirds the age of the fields in the semiarid section.

In the semihumid section the results resemble both the semiarid and the humid. In some cases the alfalfa soil has more nitrogen than the native sod, and in other cases the native sod has the more. The fields here were somewhat older than in the humid section, but on the average not as old as those in the semiarid.

Thus far the comparison is direct and simple. When the attempt is made to figure how much nitrogen has been stored in these alfalfa soils the problem becomes complicated. The nitrogen content of the fields in alfalfa at the time when these soils were first seeded is not known. All had been in cultivation for some time; this time was longest in the humid section and shortest in the semiarid. As soon as native sod is broken up and cultivation commences, loss of nitrogen begins. Some of the nitrogen is removed by the crop, but, as is well known to students of soil chemistry, the greater relative loss in new soil is through decomposition and oxidation of the organic mat-

TABLE I.—*Percentage of nitrogen in different strata of some Kansas soils.*

HUMID SECTION.

| County. | Soil No. | Description of soil. | | Depth of sample. | | | |
|---|---|---|---|---|---|---|---|
| | | Treatment. | Character. | 0–7 in. | 7–20 in. | 20–40 in. | 40–80 in. |
| Brown...... | 1768 | Alfalfa 28 years | Rolling upland | 0.211 | 0.142 | 0.062 | 0.031 |
| Do. ...... | 1770 | Native pasture, white clover | Do. | .229 | .133 | .073 | .048 |
| Do. ...... | 1769 | Cropped to grain 45 years | Do. | .160 | .135 | .066 | .031 |
| Nemaha..... | 1765 | Alfalfa 21 years | Do. | .171 | .081 | .032 | .008 |
| Do. ..... | 1767 | Native pasture, blue stem | Do. | .181 | .085 | .028 | .008 |
| Do. ..... | 1766 | Cropped to grain 45 years | Do. | .160 | .135 | .066 | .031 |
| Leavenworth. | 1318 | Alfalfa 14 years | Do. | .222 | .177 | .121 | |
| Do. | 1319 | Native meadow, blue stem | Do. | .296 | .225 | .144 | .082 |
| Montgomery | 1294 | Alfalfa 12 years | Upland | .131 | .106 | .054 | .031 |
| Do. | 1296 | Native meadow, blue stem | Do. | .186 | .114 | .067 | .024 |
| Do. | 1295 | Cropped to grain 35 years | Do. | .110 | .094 | .050 | .039 |
| Do. | 1297 | Alfalfa 10 years | Do. | .168 | .087 | .038 | .028 |
| Do. | 1298 | Cropped to grain 40 years | Do. | .135 | .076 | .043 | .026 |
| Dickinson... | 1874 | Alfalfa 20 years | Bottom | .168 | .117 | .084 | .051 |
| Do. ... | 1876 | Native meadow, blue stem | Do. | .204 | .134 | .109 | .062 |
| Do. ... | 1875 | Cultivated, mostly corn, 35 years | Do. | .140 | .101 | .084 | .062 |
| Do. ... | 1877 | Alfalfa 20 years | Upland | .179 | .134 | .077 | .060 |
| Do. ... | 1879 | Native pasture, blue stem | Do. | .204 | .131 | .080 | .066 |
| Do. ... | 1878 | Cultivated, grains, 40 years (manured) | Do. | .163 | .120 | .070 | .069 |
| SEMIHUMID SECTION. | | | | | | | |
| Mitchell..... | 1771 | Alfalfa 24 years | Bottom | .203 | .098 | .034 | .020 |
| Do. ..... | 1772 | Cultivated 30 years | Do. | .180 | .093 | .033 | .017 |
| Do. ..... | 1774 | Alfalfa 24 years | Upland | .269 | .101 | .090 | .045 |
| Do. ..... | 1773 | Native pasture | Do. | .238 | .140 | .067 | .062 |
| Do. ..... | 1779 | Alfalfa 23 years | Bottom | .160 | .068 | .062 | .048 |
| Do. ..... | 1778 | Native pasture | Do. | .180 | .069 | .048 | .026 |
| Do. ..... | 1777 | Cropped 30 years | Do. | .129 | .058 | .069 | .064 |
| Osborne..... | 1783 | Alfalfa 20 years | Do. | .184 | .101 | .062 | .039 |
| Do. ..... | 1784 | Native pasture | Do. | .250 | .120 | .066 | .038 |
| Do. ..... | 1782 | Cropped 40 years | Do. | .134 | .096 | .050 | .033 |
| Do. ..... | 1787 | Alfalfa 33 years | Do. | .196 | .095 | .084 | |
| Do. ..... | 1789 | Native wood | Do. | .220 | .115 | .092 | |
| Do. ..... | 1788 | Cultivated 35 years | Do. | .143 | .078 | .046 | |
| SEMIARID SECTION. | | | | | | | |
| Finney...... | 1299 | Alfalfa 20 years | Upland, not irrigated | 0.168 | 0.085 | 0.047 | 0.040 |
| Do. ...... | 1300 | Native range | Not irrigated | .137 | .084 | .038 | .048 |
| Do. ...... | 1303 | Alfalfa 27 years | Bottom, irrigated | .200 | .113 | .067 | .035 |
| Do. ...... | 1302 | Native buffalo grass | Not irrigated | .135 | .086 | .050 | .031 |
| Do. ...... | 1301 | Cropped to grains 20 years | Irrigated | .134 | .101 | .058 | .033 |

TABLE I.—*Percentage of nitrogen in Kansas soils.*—Continued.
SEMIARID SECTION.—Continued.

| County. | Soil No. | Description of soil. | | Depth of sample. | | | |
|---|---|---|---|---|---|---|---|
| | | Treatment. | Character. | 0–7 in. | 7–20 in. | 20–40 in. | 40–80 in. |
| Finney...... | 1304 | Alfalfa 27 years | Bottom, not irrigated | .178 | .080 | .048 | .020 |
| Do. ...... | 1305 | Cropped to wheat 27 years | Bottom, not irrigated | .079 | .057 | .039 | .012 |
| Do. ...... | 1306 | Alfalfa 30 years | Bottom, irrigated | .192 | .082 | .040 | .010 |
| Do. ...... | 1308 | Native pasture | Bottom, irrigated | .099 | .052 | .048 | .028 |
| Do. ...... | 1307 | Cropped to grains 30 years | Bottom, irrigated | .097 | .066 | .036 | .010 |
| Ford........ | 1310 | Alfalfa 30 years | Bottom, not irrigated | .210 | .085 | .069 | .075 |
| Do......... | 1311 | Native buffalo grass | Bottom, not irrigated | .171 | .108 | .061 | .073 |
| Do......... | 1312 | Cropped to grains 30 years | Bottom, not irrigated | .136 | .079 | .057 | .055 |
| Wallace..... | 1811 | Alfalfa 25 years | Bottom, irrigated | .182 | .101 | .039 | |
| Do. ..... | 1812 | Native range | Bottom, not irrigated | .151 | .088 | .052 | |
| Sheridan.... | 1806 | Alfalfa 20 years | Bottom | .187 | .107 | .057 | .043 |
| Do. .... | 1807 | Native grass | Do. | .182 | .115 | .064 | .033 |
| Do. .... | 1808 | Cropped 20 years | Do. | .118 | .057 | .034 | .022 |
| Do. .... | 1809 | Alfalfa 20 years | Upland | .153 | .066 | .040 | .026 |
| Do. .... | 1810 | Native grass | Do. | .157 | .072 | .038 | .034 |

ter. The rate of this loss decreases as time goes on. The amount removed by the crop depends on the size of the crop. Then there is a small amount of nitrogen restored to the soil by means other than legumes. The relative value of these as nitrogen restorers has been less studied than the legumes.

In no case, except in the fields in the semiarid part of the state, has a continuous growth of alfalfa stored enough nitrogen to make the content in the soil equal to or more than that in the native sod. As the nitrogen content in the alfalfa soil is greater than in the soil continuously cropped, however, it means either that the alfalfa has stored nitrogen so that the content is greater than it was when the alfalfa was sown, or that the nitrogen content has simply been maintained. Which one of these is predominating must be calculated on certain assumptions.

That alfalfa, like other legumes, has power to take nitrogen from the air is a well-recognized fact, but just how much it takes from the air and how much from the soil is not so well known. It is known

that alfalfa, like other legumes, does take nitrogen from the soil and that the proportion taken is greater in soils rich in nitrogen. Dr. C. G. Hopkins expresses the opinion in his Soil Fertility and Permanent Agriculture that legumes on the average take as much nitrogen from the air as is stored in the tops, and as much as is stored in the roots has come from the soil. This would mean that where the crop was entirely removed as hay, the growing of alfalfa would simply maintain an equilibrium. On all these fields, as far as known to the writer, the hay crop was removed and no manures or fertilizers of any kind applied.

In Table 2 are presented the calculated results from the places where the three fields, alfalfa, native sod, and cultivated, were closest together. The analytical data, calculated as pounds per acre in the surface soil (0–7 inches) for the three fields is given in columns 2, 3, and 4. In columns 5 and 6 are given the number of years of continuous alfalfa production and the number of years of continuous grain production. By subtracting the figures in column 4 from those in column 3, the loss of nitrogen through grain growing is obtained. These figures are given in column 7. The average yearly loss is obtained by dividing this loss by the number of years in cultivation. This average yearly loss is only approximate, because, as above noted, the rate is a diminishing one. This figure for the average yearly loss is probably the best one to use for the present purpose. By multiplying the average annual rate of loss into the number of years the land was in cultivation before the alfalfa was seeded, the amount of loss sustained during the period between breaking up of the native sod and the seeding of alfalfa is obtained. The figures so obtained are given in column 9. This loss no doubt is too small, for the reasons given. By subtracting the figures in column 9 from those in column 3 the amount of nitrogen present in the soil when the alfalfa was seeded is obtained. The figures so obtained are given in column 10. By comparing the figures in column 10 with those in column 2, the gain or loss of nitrogen in the soil is obtained. These figures are given in column 11.

Only three fields in the semiarid part of the state show a large gain. The losses in some of the others more than overbalance the gains in the rest. This simply means that the continuous growing of alfalfa where all the hay crop has been removed has not added to the stock of nitrogen in the soil. All that the growing of alfalfa on these fields has done, over and above grain growing, has simply been to prevent further losses or add enough nitrogen from the air to take the place of what is lost.

TABLE 2.—*Gain or loss of nitrogen in pounds per acre in fields devoted to the continuous growing of alfalfa.*

| County. | Pounds of nitrogen per acre. | | | Years in alfalfa. | Years in grain crop. | Loss of nitrogen. | | | Pounds of nitrogen when seeded. | Gain or loss while in alfalfa. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Alfalfa. | Native. | Cropped. | | | Total loss by cropping. | Average yearly loss. | Loss before seeding to alfalfa. | | |
| Brown | 4,220 | 4,580 | 3,200 | 28 | 45 | 1,380 | 31 | 527 | 4,050 | + 170 |
| Nemaha | 3,420 | 3,620 | 3,200 | 21 | 45 | 420 | 9 | 216 | 3,400 | + 20 |
| Montgomery | 2,620 | 3,720 | 2,200 | 12 | 35 | 1,520 | 43 | 989 | 2,730 | − 190 |
| Dickinson | 3,360 | 4,080 | 2,800 | 20 | 35 | 1,280 | 37 | 555 | 3,530 | − 170 |
| Do. | 3,580 | 4,080 | 3,260 | 20 | 40 | 820 | 20 | 400 | 3,680 | − 100 |
| Sheridan | 3,740 | 3,640 | 2,360 | 20 | 20 | 1,280 | 64 | 0 | 3,640 | + 100 |
| Mitchell | 3,200 | 3,600 | 2,580 | 23 | 30 | 1,020 | 34 | 238 | 3,370 | − 170 |
| Osborne | 3,680 | 5,000 | 2,680 | 20 | 40 | 2,320 | 58 | 1,160 | 3,840 | − 160 |
| Do. | 3,920 | 4,400 | 2,860 | 33 | 35 | 1,540 | 44 | 88 | 4,310 | − 390 |
| Finney | 4,000 | 2,700 | 2,680 | 27 | 20 | 20 | 0 | 0 | 2,700 | +1,300 |
| Do. | 3,840 | 1,980 | 1,940 | 30 | 30 | 40 | 0 | 0 | 1,980 | +1,860 |
| Ford | 4,200 | 3,420 | 2,720 | 30 | 30 | 700 | 23 | 0 | 3,420 | + 780 |

Further study will show that on the whole the alfalfa plant takes less nitrogen from the air than is stored in the leaves and stems. The harvesting of the crop as hay does not mean that all that which has grown above the soil is removed. Anyone who is at all familiar with the process of alfalfa hay making knows that, in spite of the most careful methods, large losses of leaves occur. These leaves contain on the average over twice the percentage of nitrogen that is present in the stems. Approximately half of the plant is leaves. In an experiment at the Kansas Agricultural Experiment Station, the loss of leaves, calculated from differences in nitrogen content in the alfalfa sampled as hay with usual loss of leaves and that sampled without loss of leaves averaged all the way from 7 to 25 percent of all the leaves, or from 3 to 14 percent of the entire crop. It was also noted that the loss of leaves was larger in a dry season than in a wetter one. These experimental data are in accord with practical experience. A man who has had very extensive experience with growing alfalfa under irrigation stated to the writer that it was a most difficult crop to save and that the greatest difficulty was to prevent the loss of leaves.

If alfalfa had taken as much nitrogen from the air as is stored in the plant above ground the soils should have shown a gain of nitrogen. It is safe to assume that in practical hay making 20 percent of the leaves are lost. When the cutting is delayed through bad weather many fall to the ground before the crop is cut. Experiments have shown that in bad weather as much as half the crop is

lost. The nitrogen added to the soil in these ways should produce an increase in the total amount present. The leaves contain 3.5 percent or more of nitrogen. A yield of 5,000 pounds per annum is a safe estimate. If the leaves are half the crop and 20 percent is left on the ground this amounts to 17.5 pounds of nitrogen annually, or 350 pounds in twenty years. In the soils sampled, except in the semiarid section, the calculated losses more than offset the gains.

A few words of explanation in regard to apparent increased crop-producing power of the soil after it has been in alfalfa for some time is desirable. This is entirely possible without an increase in the stock of potential fertilizing elements of the soil. The crop-producing power of the soil depends on several factors. Any soil which has been used for a perennial crop has an improved physical condition. The alfalfa roots contain a large amount of organic matter, and as this decays many benefits to the soil follow. Attention may be called to the fertilizing elements in alfalfa roots.[6] The average percentages of the most important fertilizing elements were as follows: Nitrogen, 2.10; phosphorus, 0.19; potassium, 1.34; and calcium, 0.62. The average percentage of these elements in the alfalfa plant as a whole, one tenth bloom, was: Nitrogen, 2.63; phosphorus, 0.18, potassium, 2.82; and calcium 1.07. On the whole the roots are poorer in these elements than the top. When an alfalfa field is plowed up large amounts of these elements become available to succeeding crops. What the alfalfa has done for the soil is to prepare a large amount of available plant food. This is what causes the increased productiveness, not necessarily indicating that the potential plant food has been increased.

The importance of these results cannot be over-emphasized. Alfalfa has been and is one of the greatest crops in this and adjoining states. Its potential power to add not only to the sources of stock feed but also to the fertility of the soil is great. But these results show that the fields which produce the alfalfa do not get this benefit. Whatever nitrogen from the air is transformed into compounds available for grain crops is transferred to other places. If it is not wasted after this transference all would be well, but even superficial knowledge of present conditions leads one to believe that most of it is wasted. Radical changes in some practices connected with conserving of soil fertility are needed.

[6] These roots were dug by Prof. Ralph Kenney in cooperative work conducted at this experiment station.

SUMMARY.

1. Kansas has a number of alfalfa fields which have been continuously in this crop for twenty to thirty years or more. The older fields are found in the central and western part of the state. Near these fields generally are fields which are in native sod used as pastures or as hay land, and fields which have been used continuously for grain growing for thirty to forty years or more. By sampling these fields in close proximity, data are secured from which the increase or decrease in the nitrogen content of the soil in alfalfa can be calculated.

2. By assuming that the fields now in alfalfa had the same nitrogen content originally as the field now in native sod and that the average annual rate of loss before the alfalfa was seeded was the same as that of the fields used for continuous grain growing, the nitrogen content at the time the alfalfa was seeded can be calculated. By comparison with the results of the three fields at the present time, calculation can be made of the increase or decrease of nitrogen content due to the growing of alfalfa.

3. In no fields in alfalfa is the nitrogen content equal to that in native sod, except a few in the semiarid portion of the state, where it was greater. In most cases in the central and eastern parts of the state the nitrogen content of the alfalfa field is greater than that of the field used for continuous grain growing. By accounting for that lost before the alfalfa was seeded and comparing with the amount present in the soil now, it is found that on the whole the growing of alfalfa has not added to the amount present in the soil, except in a few fields in the semiarid portion of the state. All that the alfalfa has done has been to prevent further losses or, in other words, to maintain an equilibrium.

# CORRELATIONS BETWEEN EAR CHARACTERS AND YIELD IN CORN.[1]

H. H. LOVE AND J. B. WENTZ.

## INTRODUCTION.

In the early history of the corn show as an element in our agricultural education, the judges were confronted with the problem as to what points should be taken into consideration and the relative weight which should be given each point in placing one sample of corn above another. In 1886 the judges at the corn exposition in Chicago prepared a scale of points to be used at that exposition and from this the score card, based upon an ideal type, was developed. After the score card had come into general use a few experimenters conducted tests in which they compared the yields obtained from selected seed ears varying in the characters emphasized in the score card. In some of these tests the seed ears were selected for several generations for the two extremes in each character studied and the yields of the selected ears were compared.

The data in this paper deal with the correlation of seed-ear characters and yield when the seed ears are not selected for extremes in the particular characters studied, but are nearer the average ear type. The purpose of the paper is to throw some light on the question as to whether a grower should select seed ears that have, for example, a certain number of rows of kernels, or a certain length of ear, or a cylindrical or tapering ear.

## EARLIER WORK.

Williams[2] of the Ohio station has conducted rather extensive and interesting experiments in which he selected seed ears for a number of years for the extremes in such characters as length of ear, shape of ear, filling of tip, indentation of kernel, weight of ear, and percentage of grain. In selecting long and short ears he obtained a difference of only 1.39 bushels per acre in 10-year average yield in favor of the long ears. In selection for shape of ear the tapering ears

[1] Paper No. 63, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Received for publication May 21, 1917.

[2] Williams, C. G. Corn experiments. Ohio Agr. Expt. Sta. Bul. 282. 1915.

excelled cylindrical ears in average yield in a 9-year period by 1.65 bushels per acre. Eight years' selection for bare as compared to filled tips gave an average difference of 0.34 bushel per acre in favor of filled tips. Seven years' selection of rough as compared to smooth dented ears gave an average difference of 1.76 bushels per acre in favor of the smooth type. Seed ears averaging 88.16 percent of grain gave a 6-year average yield of 64.64 bushels per acre as compared to 65.06 bushels from ears averaging 76.38 percent of grain.

Hartley,[3] in a tabulation of yields of four varieties for six years, embracing 1,000 ear-to-row tests of production, found no relation between the characters of seed ears and yield.

Montgomery[4] of the Nebraska station selected seed ears continuously for such characters as shape of ear, shape of kernel, and size of ear. He concludes that the results favor slightly a rather long seed ear, that size of ear depends too much upon environment to be of any importance, and that a medium depth of kernel is to be preferred.

Pearl and Surface[5] of the Maine station conducted experiments with sweet corn in 1907, 1908, and 1909, making a large number of ear-to-row tests. Two types of commercial sweet corn were used and a complete study made of a number of characters. While this work was not primarily a study of the relation of seed-ear characters to yield, one of the conclusions drawn from the data obtained was that there is no relation between the external seed-ear characters and yield in sweet corn.

Sconce[6] of Illinois, experimenting with Reid Yellow Dent and Johnson County White corn for five years, found that seed ears of these varieties with 18 and 20 rows of kernels gave better yields than those with more than 20 or less than 18 rows. Averaging four years' results with these two varieties it was found that in the case of the Reid Yellow Dent the kernels having small germs gave better yields, while in Johnson County White the kernels with large germs yielded best. In correlating yield with shape of kernel it was found in both varieties that square-shouldered kernels showing a small space between rows at the crown and tip gave the best yields.

[3] Hartley, C. P. Progress in methods of producing higher yielding strains of corn. U. S. Dept. Agr. Yearbook, p. 309. 1909.

[4] Montgomery, E. G. Experiments with corn. Nebr. Agr. Expt. Sta. Bul. 112. 1909.

[5] Pearl, Raymond, and Surface, Frank M. Experiments in breeding sweet corn. Maine Agr. Expt. Sta. Bul. 183. 1910.

[6] Sconce, H. J. Scientific corn breeding. Proc. Amer. Breeders' Asso., 7: 43. 1911.

McCall and Wheeler[7] of Ohio State University calculated the correlations between a few ear characters and yield. The data were taken from some results obtained at the Ohio station and the correlation coefficients are given in Table 1.

TABLE 1.—*Correlations between ear characters and yield of corn, as reported by McCall and Wheeler.*

| Characters correlated with yield. | Coefficients of correlation. Series 1. | Series 2. |
|---|---|---|
| Length of seed ear | .0580 ± .0296 | .1017 ± .0651 |
| Weight of seed ear | —.0270 ± .0292 | .0866 ± .0656 |
| Circumference of seed ear | —.0968 ± .0287 | .1803 ± .0636 |
| Density of seed ear | .0272 ± .0293 | |

The seed ears used in this work had not been selected for the characters used in the correlations.

In 1912, the senior author of this paper published the results of two years' study with two varieties.[8] He correlated the characters of length, weight, number of rows, weight of kernel, ratio of tip circumference to butt circumference, and percentage of grain on the seed ear with yield per stalk. The correlations obtained are given in Table 2.

TABLE 2.—*Correlations between ear characters and yield of stalk, as reported by Love.*

| Seed-ear characters correlated with yield per stalk. | Minnesota No. 13. | | Funk Ninety Day. | |
|---|---|---|---|---|
| | 1909. | 1910. | 1909. | 1910. |
| Length | −.099±.076 | .241±.064 | .300±.061 | .058±.067 |
| Weight | .094±.076 | .015±.068 | .323±.060 | .090±.067 |
| Number of rows | .260±.072 | −.127±.067 | −.061±.069 | −.034±.067 |
| Weight of kernels | ............ | .028±.068 | ............ | .043±.067 |
| Ratio of tip circumference to butt circumference | ............ | −.162±.066 | ............ | .014±.067 |
| Percentage of grain | ............ | −.177±.066 | ............ | ............ |

The only characters that show any considerable correlations with yield in Table 2 are length and weight of seed ear. Of the eight correlations obtained for these two characters in the two years, two are about five times their probable errors, while others are actually less then their probable errors, so that these correlations can hardly be considered significant. In his work Love used Funk Ninety Day

[7] McCall, A. G., and Wheeler, C. S. Ear characters not correlated with yield in corn. Jour. Amer. Soc. Agron., 5: 117. 1913.

[8] Love, H. H. The relation of certain ear characters to yield in corn. Proc. Amer. Breeders' Asso., 7: 29. 1912.

and Minnesota No. 13 and the same methods were employed as are used in this paper. The present paper really is a continuation of this earlier work, using the Funk Ninety Day[9] over a period of five years. In addition to the characters studied in the earlier paper other characters have been correlated with yield. The correlation coefficients were calculated in the usual manner and carefully checked by independent workers.

Cunningham[10] of the Kansas station recently published a paper recording studies of the relation of seed-ear characters to yield in a number of varieties. The material used was from some ear-to-row tests that had been conducted by the station in its corn improvement work. The seed ears were classified for the characters studied and the average yield of each class determined. There was some variation for length of ear in the different varieties. In the small varieties the long ears yielded a little better than the medium and short ears, but this did not hold true in the larger varieties. There was no significant difference in the averages for all varieties. Ears with small circumference outyielded the larger ears. There seems to be no relation between the filling out of the tips of the seed ears and yield. Smooth ears outyielded the roughly dented ears. Ears with low percentage of grain yielded slightly higher than those with the higher percentages of grain. Ears with 16 and 18 rows of kernels generally produced the highest yields, although there was a difference in varieties in this character.

## Material Used in the Present Work.

The corn used in this work is Cornell No. 12, a selection from Funk Ninety Day, a yellow dent variety obtained from the Funk Bros. Seed Co. in 1908. In 1908 and 1909 it was grown on G. R. Schauber's farm at Ballston Lake, N. Y. In 1910 half of each seed ear was planted in a plat on Mr. Schauber's farm and the other half in a new plat on Broad Brook Farm at Bedford Hills, N. Y., owned by the late Seth Low. The data since 1909 came from the latter plat.

## Methods.

The characters studied are length, average circumference, average cob circumference, and weight of ear; number of rows; average

[9] This corn has been selected for some time for earliness and yield. In part it is different in these two characters from the original sort and is now called Cornell No. 12.

[10] Cunningham, C. C. Relation of ear characters of corn to yield. Jour. Amer. Soc. Agron., 8: 188. 1916.

weight, average length, and average width of kernels; and percentage of grain. All the measurements were taken in centimeters and all weights, excepting yield, were taken in grams. The yield of each row was taken in pounds and the yield per row divided by the number of stalks in the row to obtain the yield per stalk. The average circumferences of the ear and of the cob were obtained by averaging the tip and butt circumferences. The ratio of the tip circumference to the butt circumference was obtained by dividing the tip circumference by the butt circumference. In this way the shape of the ear was determined. The lower this ratio, the more tapering would be the ear. To determine the average weight of kernels, the number of kernels per ear was calculated by multiplying the number of kernels per row by the number of rows on the ear, and then dividing the weight of grain by the number of kernels. The average length and width of kernels was determined by taking the measurements of 10 kernels and averaging these measurements. The percentage of grain was calculated by dividing the weight of shelled corn by the weight of the ear.

## Results.

Table 3 shows the correlations obtained for all the characters for each of the five years. In this table the correlations obtained by Love, working with this same lot of corn in 1909 and 1910, are also included, so that correlations for seven years are shown for some of the characters.

The only very significant correlations in Table 3 are seen where the average circumference of the seed ear is correlated with yield and these are not consistently high. These correlations seem to show some slight relation between the circumference of the seed ear and yield, indicating that the larger the circumference the greater the yield per stalk. It is noted that the correlations for average circumference of cob and for weight of seed ear are all positive, although they are all small. This may mean that there is a slight relation between the size of the seed ear and yield, so that the larger ear may tend to give slightly the larger yield. However, length of seed ear shows no constant relation to yield.

It is interesting to note that the correlations between the percentage of grain in the seed ear and yield are all negative. While these correlations are all too small to be of any significance they rather confirm the results Williams obtained in studying this character. It is not thought necessary to publish the correlation tables in detail in this paper. These correlations on the whole are so low that it seems

TABLE 3.—*Summary of correlations with yield per stalk in a study of a strain of Funk Ninety Day corn, 1909 to 1914.*

| Characters of seed ear correlated with yield per stalk. | Coefficient of correlation. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1909. | 1910. | 1910. | 1911. | 1912. | 1913. | 1914. |
| Length | .300±.061 | .058±.067 | .013±.067 | −.013±.067 | −.102±.069 | .026±.067 | .165±.066 |
| Average circumference | ........ | ........ | .187±.065 | .249±.063 | .360±.061 | .104±.067 | .134±.067 |
| Ratio of tip to butt circumference | ........ | .014±.067 | −.037±.067 | −.087±.067 | .019±.070 | .085±.067 | −.131±.067 |
| Average circumference of cob | ........ | ........ | .169±.066 | .126±.066 | .274±.064 | .130±.066 | .185±.066 |
| Weight | .323±.060 | .090±.067 | .023±.067 | .108±.067 | .249±.065 | .156±.066 | .099±.067 |
| Percentage of grain | ........ | ........ | −.102±.067 | −.173±.065 | −.051±.069 | −.046±.067 | −.183±.066 |
| Average weight of kernels | ........ | .043±.067 | −.105±.067 | −.114±.067 | .112±.069 | −.152±.066 | .082±.068 |
| Number of rows | .061±.069 | .034±.067 | .113±.067 | .097±.067 | .083±.069 | −.067±.067 | .032±.068 |
| Average length of kernels | ........ | ........ | ........ | .038±.067 | ........ | ........ | −.043±.068 |
| Average width of kernels | ........ | ........ | ........ | .162±.066 | ........ | ........ | .065±.068 |

TABLE 5.—*Annual and average means of the characters studied in the seed ears for each of the five years from 1910 to 1914.*

| Characters. | Means. | | | | | |
|---|---|---|---|---|---|---|
| | 1910. | 1911. | 1912. | 1913. | 1914. | Average. |
| Length | 19.310± .099 | 22.230± .099 | 20.830± .093 | 21.920± .115 | 22.622± .092 | 21.382± .045 |
| Average circumference | 14.520± .050 | 15.420± .053 | 15.340± .067 | 15.640± .063 | 15.469± .057 | 15.278± .027 |
| Ratio of tip to butt circumference | .891± .002 | .876± .002 | .854± .003 | .856± .002 | .817± .003 | .859± .001 |
| Average circumference of cob | 9.020± .043 | 9.260± .037 | 9.186± .045 | 9.255± .038 | 9.724± .042 | 9.289± .018 |
| Weight | 198.400±1.675 | 292.800±1.879 | 273.400±2.449 | 298.800±2.446 | 301.840±2.285 | 273.048± .970 |
| Percentage of grain | 84.100± .158 | 85.660± .176 | 84.947± .165 | 85.940± .167 | 85.612± .144 | 85.252± .073 |
| Average weight of kernels | .226± .002 | .295± .002 | .288± .003 | .311± .003 | .293± .003 | .283± .001 |
| Number of rows | 16.980± .133 | 17.220± .119 | 16.660± .147 | 16.820± .131 | 17.340± .152 | 17.004± .061 |
| Average length of kernels | ........ | 1.314± .005 | ........ | ........ | 1.314± .005 | 1.314± .003 |
| Average width of kernels | ........ | .772± .004 | ........ | ........ | .824± .004 | .798± .003 |
| Yield | .858± .005 | .669± .003 | .712± .005 | .764± .004 | .634± .003 | .727± .002 |

there is no relation between the seed-ear character and yield; at least, there is not enough evidence to justify one in attempting to improve the yield of his corn by selecting any particular type for seed.

In Table 4 the mean percentages of grain for the ears in a few of the highest classes and a few of the lowest classes in the correlation tables are shown, with the mean yields of these classes. In this table it will be noticed that in every case the seed ears with the lowest percentage of grain gave slightly higher yields.

TABLE 4.—*Mean percentages of grain in the seed ears in a few of the highest and lowest classes, with the mean yields of these classes.*

| Year. | High classes. | | Low classes. | |
|---|---|---|---|---|
| | Percentage of grain. | Yield per stalk, pounds. | Percentage of grain. | Yield per stalk, pounds. |
| 1910.......... | 87.074 | 0.822 | 81.676 | 0.859 |
| 1911.......... | 88.565 | 0.624 | 79.375 | 0.677 |
| 1912.......... | 87.158 | 0.672 | 80.750 | 0.738 |
| 1913.......... | 88.447 | 0.692 | 80.714 | 0.847 |
| 1914.......... | 87.235 | 0.651 | 82.750 | 0.645 |
| Average..... | 87.596 | 0.692 | 81.053 | 0.753 |

In addition to the correlations between the seed ear characters and yields, the means, standard deviations, and coefficients of variability were calculated for the seed ears for each year. It may be of interest to note the means of the characters studied. These constants are shown in Table 5.

In Table 5 there seems to be a slight tendency for the ears to grow longer. The ratio of tip circumference to butt circumference has decreased slightly, meaning that the ears seem to have become more tapering. The weight of the ears has increased considerably. In looking at the means of the yields it may appear as though there has been a slight decrease in yield, since the yield in 1910 was so much higher than in any of the following years. This higher yield can, in most part, be accounted for by the fact that in this year the corn was not so mature as it has been in the succeeding years. Considerable green corn was produced the first year, while the following year at harvest time the corn was nearly all mature.

## CONCLUSIONS.

1. The characters of length, ratio of tip circumference to butt circumference, average circumference of cob, weight, average weight of kernels, number of rows of kernels, and average length and width of

kernels on the seed ears do not show correlations significant enough to be of value in judging seed corn.

2. The data indicate a slight negative correlation between percentage of grain in the seed ear and yield, meaning that possibly ears containing a low percentage of grain yield higher than ears with a high percentage of grain.

3. The average circumference of the seed ear is the only character that shows any significant relation to yield.

4. The judge at a corn show or a farmer in selecting his seed corn cannot pick the high-yielding seed ears when judging from outward characters of the ears. It is evident that the points emphasized on a score card are of no value for seed ear purposes and are entirely for show purposes.

5. The only basis left for selecting high yielding seed corn is the ear-to-row progeny test.

## VEGETATION ON SWAMPS AND MARSHES AS AN INDICATOR OF THE QUALITY OF PEAT SOIL FOR CULTIVATION.[1]

T. J. DUNNEWALD.

The general conclusion of various observers has been that the surface vegetation on peat gives no clue to the relative quality of the soil for purposes of cultivation. Among the reasons given as to why this is so, the following are important:

That in the natural development of a peat bog there is a more or less rigid succession of plant types and that tamarack and spruce timber indicate only that the deposit is in a mature stage of its growth.

That such accidents as fire, epidemics of plant disease or pests, changes from a series of dry years to one of wet years, changes in the elevation of the water table of the deposit, etc., may serve to destroy entirely one type of vegetation and create conditions more favorable to very different kinds of plants.

On the other side of the question are the oft-repeated assertions of farmers and drainage men that "the peat on a black spruce or moss-covered swamp is no good for cropping and money spent in draining it is wasted," while "good black muck with elm or ash on it is the best kind of land to drain."

[1] Contribution from the Wisconsin Agricultural Experiment Station, Madison, Wis. Received for publication March 2, 1917.

One of the duties of the writer has been to examine, map, and write a preliminary report on the soil of proposed drainage districts under the State drainage law. One such area examined consisted of a township in the northwestern county of Wisconsin, which contained about 6,600 acres of scattered marshes and swamps.

The upland is non-calcareous glacial drift derived from granitic and sandstone rocks, with no limestone in the vicinity. Admitting that there might be mechanical and physical conditions in the peat soil of these areas which might make it favorable or unfavorable for cultivated plant growth, the writer wished to know whether a favorable or unfavorable chemical condition could be found in different areas of the peat and whether the vegetation would parallel any such condition.

In addition to a careful field examination, representative samples of the peat bearing different classes of vegetation were taken to the laboratory for examination.

As a result of the field study alone it was concluded that the spruce and tamarack peat areas were the wettest, with the water-table practically at the surface of the soil and a covering of 12 to 18 inches of spongy moss. The depth of the peat or distance from shore seemed to affect the kind of surface growth but little, and the extent of the decomposition of the peat, that is, its fine grained or fibrous condition, had but little more effect. The rawest samples of peat were found on the spruce and tamarack areas, but as often the peat was as well decomposed under spruce and tamarack as under elm, birch, ash, and grass.

The examination of the samples in the laboratory gave somewhat more positive results. Table 1 gives a summary of the more interesting determinations which were made. These data indicate that the peat bearing black spruce and tamarack has 20 percent less mineral matter, a much greater degree of acidity, and somewhat less nitrogen.

While the greater acidity present in the spruce and tamarack peats may be due to more continued flooded conditions on those swamps and while drainage experience shows that this acidity often disappears largely after the drainage and cultivation of the peat, we believe the data support the farmer's statement that such trees as ash, elm, birch and white pine on peat indicate a better quality of the material than that where only black spruce, tamarack, sphagnum moss, blueberries, and cassandra grow.

Determinations of the solubility of the peats in 150 cc. of 2 per-

cent NaOH solution showed that the acid peats were from 3 to 8 percent more soluble than the less acid ones, but when sufficient excess amount of the solvent to counteract the extra acidity of the spruce peats was used, the difference in solubility was not noticeable.

TABLE 1.—*Comparative determinations on peat soils in the same locality bearing different classes of vegetation.*[a]

| No. of soil.[b] | Vegetation. | Loss on ignition. | Truog acidity. | Total nitrogen. |
|---|---|---|---|---|
| | | % | | % |
| 2 | Tamarack | 78.56 | Very strong | 1.58 |
| 4 | Tamarack and moss | 79.11 | Strong | 1.98 |
| | Average | 78.80 | Strong | 1.78 |
| 5 | Black spruce and moss | 85.48 | Very strong | 1.86 |
| 8 | do | 91.07 | Very strong | 1.86 |
| 9 | do | 90.89 | Very strong | 1.90 |
| 11 | do | 88.14 | Very strong | 1.69 |
| 14 | do | 93.01 | Very strong | 1.82 |
| | Average | 88.90 | Very strong | 1.81 |
| 1 | Mixed ash, birch and balsam | 60.61 | Very slight | 1.96 |
| 3 | Large ash, birch, poplar, and cedar | 81.01 | Slight | 2.17 |
| 6 | Birch, ash, elm | 66.91 | Medium | 2.02 |
| 7 | Mixed birch, ash, tamarack, and willow | [c]56.85 | Slight | — |
| 10 | Ash, birch, and a few large tamarack and pine | 47.14 | Medium | — |
| 17 | Elm, ash, cedar, and grass | 62.08 | Medium | 2.20 |
| | Average | 67.60 | Slight | 2.09 |

[a] The peat was from 6 to 20 feet deep wherever a sample was taken except in the case of No. 7.

[b] Samples Nos. 2 and 1 were taken in different parts of the same swamp.

[c] Fine sand grains were detected in Nos. 7 and 10 and they are not included in the average loss on ignition.

# SOME EFFECTS OF SUCCESSIVE CROPPING TO BARLEY.[1]

W. F. GERICKE.

## INTRODUCTION.

The work reported in this paper is part of an experiment which had as its purpose the study of some of the effects of successive cropping of barley on a soil in pots under greenhouse conditions. All the factors of production except the soil were the same or similar for the series throughout the experiment. The experiment was carried out as follows: Portions of 5 kilograms of soil were weighed out and placed in pots. Some of the pots were then sown while others remained unsown until a series was obtained some of which had produced three crops, some two crops, some one crop, and some no crop. Throughout the experiment both the culture and water content of the soil for the series were kept similar whether the pots grew plants or not.

The soil used in the experiment was a Berkeley hillside adobe to which some compost material had been added, and was in good physical condition. Proper care was taken to insure uniformity in type, texture, and composition. A sample of this soil upon analysis by the strong acid digestion method gave the following results:

| | |
|---|---|
| Insoluble residue | 64.85 |
| Soluble silica | 9.18 |
| CaO | 2.26 |
| $Fe_2O_3$ | 4.59 |
| $Al_2O_3$ | 5.80 |
| $SO_3$ | .04 |
| $Mn_3O_4$ | .13 |
| MgO | .72 |
| $K_2O$ | .62 |
| $Na_2O$ | .43 |
| $P_2O_5$ | .48 |
| Loss on ignition | 11.94 |
| Total | 101.04 |
| Total nitrogen | .31 |
| Humus | 3.20 |
| Nitrogen in humus | 3.30 |

[1] Contribution from the Laboratory of Soil Chemistry, University of California, Berkeley, Cal. Received for publication May 4, 1917.

The analysis shows that the soil was well supplied with the necessary plant-food constituents and that the nitrogen content was especially high. All of these factors must be kept in mind in reading the paper.

The seed used in the experiment was a very pure strain of Beldi barley. All the seeds planted in the pots came from two plants. After the seedlings were about 3 inches high all pots were thinned to two plants each, one from a seed from each of the plants used.

## Experimental Results.

The data recorded in the following tables includes length of period of harvest, tillering, height of stalk, and weight of grain for the individual heads, and average weight of kernel per head. The tables are arranged to bring out certain relationships. They are (*a*) those showing the different kinds of stalk production and maturation of the crops; (*b*) those showing the total and average height of the different kinds of stalks of the crops; and (*c*) those showing the quantity and quality of grain production as related to the height of the stalks in each of the crops.

### STALK PRODUCTION AND MATURITY.

The data on total number of stalks, stalks producing grain, and stalks producing heads but no grain, with the dates of first and last ripening of the various crops, are shown in Table 1.

Table 1.—*Stalk production and maturation of barley as affected by successive cropping of the same soil.*

| No. of crop. | Number of stalks. | | | | Period of harvest. | |
|---|---|---|---|---|---|---|
| | Total per pot. | Grain producing. | Producing heads but no grain. | Producing no heads. | First heads ripe. | Last heads ripe. |
| 4 | 5 | 5 | 0 | 0 | June 1 | June 11 |
| 4 | 6 | 6 | 0 | 0 | do. | do. |
| 3 | 20 | 6 | 6 | 8 | June 15 | July 7 |
| 3 | 12 | 6 | 4 | 2 | do. | July 8 |
| 2 | 21 | 6 | 10 | 5 | June 15 | July 10 |
| 2 | 23 | 8 | 9 | 6 | June 14 | do. |
| 1 | 29 | 13 | 11 | 5 | June 15 | July 8 |
| 1 | 40 | 10 | 16 | 14 | June 16 | July 12 |

Briefly discussing the data presented, Table 1 shows a difference in the length of the period of harvest, i. e., in the maturation of the heads. The plants in crop 4 had the shortest growing period because the period of maturation was much less for them than for those in

any other pots. Due to good uniformity in the ripening of the grain in crop 4, all heads produced were harvested about the same time. This fact, however, must not convey the impression that all heads had matured to the same degree of ripeness, a fact which could only be ascertained by chemical analysis. The practical criterion of ripeness in the color and hardness of grain was such as to indicate the advisability of harvest. In respect to the uniformity of maturation of the grain, the plants in crop 4 must be considered as more desirable than any of the other plants. The importance of uniformity and even ripening of grain in the field is of the utmost importance.

The plants representing the first, second, and third croppings of a soil had a very extended period of harvest. Although some heads matured a few days after those of crop 4, the fact that a period of three to four weeks was required for all heads to ripen presented conditions which if duplicated in the field would be very serious to farming practices. It is quite true that these conditions of prolonged maturation of grain could hardly be expected under field conditions when a pure strain of seed is used. Still, the fact remains that the soil conditions are important factors in contributing to uniformity and evenness in the ripening of grain. A glance at Table 1 shows that the plants which required a relatively long period of time for maturation were plants that produced a considerable number of barren stalks. The excessive tillering of plants, noted especially in the first crop, but also evident in those of the second and third crops, undoubtedly are related to soil conditions and these factors have brought about the extended period of harvest. A partial explanation of the long harvest period of these series, however, may be found in the effect of the removal of ripe heads from the plants, thereby allowing a fuller development of later-formed heads on the tillers.

While a moderate amount of tillering is a very desirable feature in grain production, too much vegetative growth in cereals often results to the detriment of grain production. As a tiller will produce grain if conditions are favorable, the time during the plant's growth when tillers appear is of great importance in procuring uniformity and evenness in the ripening of grain.

From the standpoint of the most efficient tillering of barley for grain production, in which the quality and quantity of grain are the factors of prime importance, the produce of the fourth crop must be considered the best, as a glance at Table 3, which gives the total weight and average weight of the kernels, shows. Judging then

from the standpoint of the fertility of a soil for certain features of crop production, so far as this experiment is concerned, the soil at its fourth cropping was more fertile for grain production than at its first.

The maximum dry matter production was attained in the first crop. The straw production in this crop was more than 100 percent larger than that in the fourth crop, but the grain yield exceeded that of the fourth crop by only a small margin. In the ratio of percentage yield of grain to total dry matter production the plants from the fourth cropping were far superior to those from any other crop. In the quality of grain as indicated by the average weight per kernel, the production of the fourth crop exceeded that of the first by a margin of 6½ mg. per kernel, which would make a very significant difference in the grading of the grain produced from the several crops.

Undoubtedly soil conditions were responsible for the differences noted in the plants of the several croppings. With the plant food available in different amounts and ratios of one element to another in the various crops, a condition was brought about that was reflected in the quantity and quality of the produce. In the first crop the supply of plant food, both in quantity and in the ratio of available elements one to another, was of such a magnitude as to induce an extended vegetative growth. Thus tillering was not only induced but sustained to fruition, over a relatively longer period of time.

### HEIGHT OF STALKS.

Table 2 shows the total and average heights of the stalks of the different classes.

TABLE 2.—*Height in centimeters of the different classes of stalks as affected by successive cropping of the same soil.*

| No. of crop. | Height of all stalks. | | Height of grain-producing stalks. | | Height of stalks producing heads, but no grain. | | Height of stalks producing no heads. | |
|---|---|---|---|---|---|---|---|---|
| | Total. | Average. | Total. | Average. | Total. | Average. | Total. | Average. |
| 4 | 343 | 68.6 | 343 | 68.8 | — | — | — | — |
| 4 | 400 | 66.6 | 400 | 66.6 | — | — | — | — |
| 3 | 815 | 40.7 | 319 | 53.2 | 175 | 29.2 | 321 | 40.1 |
| 3 | 471 | 38.2 | 255 | 42.5 | 110 | 27.5 | 106 | 53.0 |
| 2 | 738 | 35.1 | 298 | 49.7 | 318 | 31.8 | 122 | 24.4 |
| 2 | 732 | 31.6 | 330 | 41.2 | 266 | 29.6 | 136 | 22.7 |
| 1 | 903 | 31.1 | 502 | 38.6 | 284 | 25.8 | 117 | 23.4 |
| 1 | 1,156 | 28.9 | 409 | 49.0 | 464 | 29.0 | 284 | 20.3 |

The data in Table 2 show some of the effects of successive cropping of a soil on the height of the barley. The total height of all the stalks produced decreased for each succeeding crop, while the average height of the individual stalk increased. The tallest stalks were found in the fourth crop plants and the shortest in the first crop. The average height of the grain-producing stalks was uniformly greater than those of the non-producing stalks. In the first and second crops the barren stalks were decidedly shorter than the grain-producing stalks, while in the third crop the barren stalks attained their greatest height.

Why the plants of the fourth crop produced taller stalks than those grown on a soil that supported plants for a less number of seasons is not easy to explain. That the food requirement of plants at different periods of growth varies both in quantity and ratio of one element to another has been indicated by various investigations. The degree of absorptivity and availability of the elements by the plants in the several crops may be of importance to account for certain changes in the form and features of the plant.

### WEIGHT OF GRAIN.

Table 3 shows some of the relations between the height of the stalks and their grain production.

TABLE 3.—*Relation of height of stalk to weight of grain as affected by successive cropping of the same soil.*

FOURTH CROP.

| Stalk No. | Pot 1. | | | | Pot 2. | | | |
|---|---|---|---|---|---|---|---|---|
| | Height of stalk. | Number of kernels in head. | Weight of kernels in head. | | Height of stalk. | Number of kernels in head. | Weight of kernels in head. | |
| | | | Total. | Average. | | | Total. | Average. |
| | *Cm.* | | *Grams.* | *Mgs.* | *Cm.* | | *Grams.* | *Mgs.* |
| 1 | 83 | 39 | 1.999 | 51.3 | 84 | 37 | 1.995 | 53.9 |
| 2 | 79 | 30 | 1.540 | 51.3 | 81 | 37 | 1.872 | 50.6 |
| 3 | 78 | 32 | 1.600 | 50.0 | 73 | 35 | 1.703 | 48.6 |
| 4 | 62 | 24 | 1.187 | 49.4 | 61 | 24 | 1.111 | 46.3 |
| 5 | 42 | 6 | .230 | 38.3 | 56 | 26 | 1.021 | 39.3 |
| 6 | | | | | 45 | 16 | .619 | 38.7 |
| Totals... | 343 | 131 | 6.556 | 240.3 | 400 | 175 | 8.321 | 277.4 |
| Average . | 68.6 | 26.2 | 1.311 | 50.0 | 66.6 | 29.1 | 1.387 | 47.5 |

TABLE 3.—*Relation of height of stalk to weight of grain as affected by successive cropping of the same soil.*—Continued.

THIRD CROP.

| Stalk No. | Pot 1. Height of stalk. | Pot 1. Number of kernels in head. | Pot 1. Weight of kernels in head. Total. | Pot 1. Weight of kernels in head. Average. | Pot 2. Height of stalk. | Pot 2. Number of kernels in head. | Pot 2. Weight of kernels in head. Total. | Pot 2. Weight of kernels in head. Average. |
|---|---|---|---|---|---|---|---|---|
| | *Cm.* | | *Grams.* | *Mgs.* | *Cm.* | | *Grams.* | *Mgs.* |
| 1 | 74 | 37 | 1.921 | 52.9 | 69 | 37 | 1.940 | 52.4 |
| 2 | 63 | 26 | 1.222 | 47.0 | 64 | 29 | 1.465 | 50.5 |
| 3 | 55 | 22 | 1.027 | 46.7 | 36 | 18 | .608 | 33.8 |
| 4 | 53 | 21 | .981 | 46.7 | 34 | 21 | .896 | 42.6 |
| 5 | 48 | 21 | .893 | 42.4 | 27 | 10 | .383 | 38.3 |
| 6 | 26 | 3 | .068 | 32.7 | 25 | 3 | .073 | 24.3 |
| Total.... | 319 | 130 | 6.112 | 268.4 | 255 | 118 | 5.365 | 241.9 |
| Average . | 53.1 | 21.6 | 1.019 | 47.0 | 42.5 | 19.7 | .894 | 45.4 |

SECOND CROP.

| Stalk No. | Pot 1. Height of stalk. | Pot 1. Number of kernels in head. | Pot 1. Weight of kernels in head. Total. | Pot 1. Weight of kernels in head. Average. | Pot 2. Height of stalk. | Pot 2. Number of kernels in head. | Pot 2. Weight of kernels in head. Total. | Pot 2. Weight of kernels in head. Average. |
|---|---|---|---|---|---|---|---|---|
| 1 | 69 | 50 | 2.017 | 40.3 | 56 | 33 | 1.408 | 42.6 |
| 2 | 56 | 36 | 1.080 | 30.0 | 53 | 33 | 1.390 | 42.1 |
| 3 | 53 | 36 | 1.377 | 38.2 | 46 | 9 | .433 | 48.1 |
| 4 | 52 | 27 | 1.228 | 45.5 | 43 | 17 | .742 | 43.6 |
| 5 | 40 | 20 | .614 | 30.7 | 38 | 17 | .540 | 31.8 |
| 6 | 28 | 33 | .129 | 43.0 | 36 | 24 | 1.000 | 41.6 |
| 7 | | | | | 33 | 4 | .140 | 35.0 |
| 8 | | | | | 25 | 1 | .034 | 34.0 |
| Total.... | 298 | 172 | 6.445 | 227.7 | 330 | 138 | 5.687 | 318.8 |
| Average . | 49.7 | 28.7 | 1.074 | 37.5 | 41.2 | 17.2 | .711 | 41.2 |

FIRST CROP.

| Stalk No. | Pot 1. Height of stalk. | Pot 1. Number of kernels in head. | Pot 1. Weight of kernels in head. Total. | Pot 1. Weight of kernels in head. Average. | Pot 2. Height of stalk. | Pot 2. Number of kernels in head. | Pot 2. Weight of kernels in head. Total. | Pot 2. Weight of kernels in head. Average. |
|---|---|---|---|---|---|---|---|---|
| 1 | 50 | 42 | 1.720 | 40.9 | 58 | 34 | 1.529 | 44.8 |
| 2 | 50 | 15 | .426 | 28.4 | 56 | 33 | 1.529 | 46.4 |
| 3 | 41 | 18 | .742 | 41.2 | 50 | 22 | .977 | 44.3 |
| 4 | 41 | 14 | .567 | 40.5 | 45 | 23 | 1.085 | 47.2 |
| 5 | 40 | 20 | .804 | 40.2 | 41 | 20 | .864 | 43.0 |
| 6 | 39 | 12 | .501 | 41.8 | 36 | 10 | .409 | 40.9 |
| 7 | 39 | 22 | .836 | 38.0 | 34 | 17 | .695 | 40.9 |
| 8 | 36 | 17 | .770 | 45.3 | 33 | 4 | .146 | 36.5 |
| 9 | 36 | 7 | .299 | 42.7 | 28 | 1 | .043 | 43.0 |
| 10 | 36 | 8 | .309 | 38.6 | 28 | 1 | .038 | 38.0 |
| 11 | 34 | 27 | 1.001 | 37.0 | | | | |
| 12 | 30 | 4 | .154 | 38.5 | | | | |
| 13 | 30 | 1 | .023 | 23.0 | | | | |
| Total.... | 502 | 207 | 8.652 | 496.1 | 409 | 172 | 7.315 | 425.0 |
| Average . | 38.6 | 15.9 | .665 | 41.8 | 40.9 | 17.2 | .731 | 42.5 |

In the plants of the fourth crop, the weight of the grain per head and the average weight of the kernels varied with the height of the

stalk, the tallest stalks producing the most grain both in total weight and in the average weight of the kernels. The number of kernels per head, with a few exceptions, varied with the height of the stalk, the largest number of kernels being on the tallest stalks. In the plants of the third crop, a similar relation was found between weight of grain and height of stalk and also between number of kernels per head and height of stalk. The average height of the stalks and the average weight of their grain was less than those of the fourth crop. Grain production of this crop was the least for the series, as these plants, unlike those of the fourth crop, produced barren stalks. In the first and second crop there was a decided change in the relation of the height of stalk to the weight of grain per head and its average weight per kernel. While some of the heaviest heads were found on the tallest stalks, many of the relatively smaller heads were also found on some of the tallest stalks. The heads with the best average weight of kernels were produced on stalks of medium height. The average height of the stalks and the average weight of the kernels were less than those of the third and fourth crops. The first and fourth crops had the fewest undersized kernels and also showed the least variation from the average mean weight of kernels for the crop.

Similar to the causes given for the results in Tables 1 and 2, the differences in plant features shown in Table 3 must be ascribed to the soil conditions. The uniformly better grains of the fourth crop can only be explained by the fact that all stalks had progressed uniformly and were within a relatively narrow range of variation for the respective period. Due to the absence of new stalk development in a later period of growth, the condition was obviated by which a new stalk would detract very much from the nourishment of the other parts of the plant, or the older stalk detract from that of the younger shoots. However, as the heaviest grain, both in head and average weight per kernel, varied with the height of the stalks in the fourth crop, there were obviously some soil factors at work to produce such a condition. While the maturity of the heads in this crop was such that they were harvested about the same time, the actual growing period of the heads of the smaller stalks was less than that of the taller stalks, as the heads on the smaller stalks appeared from one to two days later. This difference gave the taller stalks such a lead as to enable them to maintain their supply of plant food over the younger stalks, all of which were within the corresponding period of development. When part of the plant was in one period

of growth and part in another, for example, when some stalks were headed out while others were still producing tillers, the plant food supplied by the same root system was influenced by a difference in the plant-food requirements of the different periods. As the amount of water in the tissues varies with different stages of growth, the translocation and assimilation of nutrients is likewise affected. It is thus when the roots must supply food and water for two different periods of development where different food requirements and assimilative powers exist, that no correlation is attained between the straw and the grain production both as to weight of grain per head and as to weight of the individual kernels. That the length of the maturation period may also effect a difference in the chemical composition of the grain has been indicated by other investigations. Soil conditions, therefore, must be considered factors that may affect crop production not only in quantity but also in quality and in composition of its produce.

## Summary.


1. In an experiment to determine some of the effects of continuous cropping of a soil under greenhouse conditions, barley was grown in pots, the successive crops being grown concurrently in order to eliminate as much as possible such factors of differences as climate and season.

2. Plants of the fourth crop matured with greater uniformity than those of any of the other crops. There were no barren stalks in the plants of the fourth crop. The number of tillers and barren stalks increased with the plants grown in the soil of a lesser number of crops.

3. The total height of all the stalks produced decreased with each successive crop, but the average height of the individual stalks increased with each successive crop.

4. In the fourth and the third crops the heaviest grain, both as to weight per head and as to average weight per kernel, varied with the height of the stalks. The tallest stalks produced the largest heads and the largest average weight per kernel.

5. In the second and first crops no correlation between the height of stalks and weight of grain per head, or average weight per kernel, was obtained.

# A STUDY OF SOIL SOLUTIONS BY MEANS OF A SEMIPERMEABLE MEMBRANE SUPPORTED ON A POROUS CLAY PLATE.[1]

GEO. L. SCHUSTER.

## INTRODUCTION.

The object of the work reported in this paper was to find out if possible the strength of various soil solutions in terms of a given sugar solution. Pulling and Livingston,[2] in their work concerning the water-supplying power of the soil, used a collodion membrane formed by the evaporation of the solvent from a solution of "Scherings celloidin" dissolved in a mixture composed of equal parts by volume of ether and alcohol. Morse[3] prepared semipermeable membranes of copper ferrocyanide in the porous walls of clay cups by using an electric current to drive the membrane-forming solutions, copper sulfate and potassium ferrocyanide, into the walls.

The membranes used in this work were prepared by Professor A. G. McCall, now of the Maryland Agricultural Experiment Station, in the following manner. Three conical-shaped cells, having a base 7.5 cm. in diameter and a neck 2.3 cm. in diameter and 3.7 cm. long, were used. The exterior surface of these cells was glazed with the exception of the bottom. They were placed in a dilute solution of lithium sulfate (0.5 gram per liter) and a similar solution added to the inside of the cells. An electric current of 7 to 8 amperes was passed from a platinum electrode situated in the solution outside the cell to another inside the cell for one hour twice a day for a period of three days. This drove the air out of the porous bottom, but in the process the solution in the cell continually bubbled over, so a funnel was provided that the solution might be readily replaced. The form of the cell and the general arrangement of the electrode, etc., are shown in figure 21.

After rinsing the lithium sulfate out, the cells were partially im-

[1] Contribution from Ohio State University, Columbus, Ohio. Received for publication April 4, 1917.

[2] Pulling, H. E., and Livingston, B. E. The water-supplying power of the soil as indicated by osmometers. Carnegie Institution of Washington, Pub. 204, p. 55–56. 1915.

[3] Morse, H. N. The osmotic pressure of aqueous solutions. Carnegie Institution of Washington, Pub. 198, p. 82–85. 1914.

mersed in tenth-normal copper sulfate and partially filled with tenth-normal potassium ferrocyanide. The cells were closed at the top with rubber stoppers carrying a wire attached to a platinum cathode (*P*), a funnel (*S*), and an overflow tube (*O*) (figure 21). A copper anode was placed in the copper sulfate outside the cell and an electric current of 7 to 8 amperes was allowed to pass through each cell for one hour each day for a week. During the periods when the current was on the potassium ferrocyanide solution was renewed every ten minutes. When the current was not on the cells were kept in distilled water and to this a small crystal of thymol was added to prevent fungous growth.

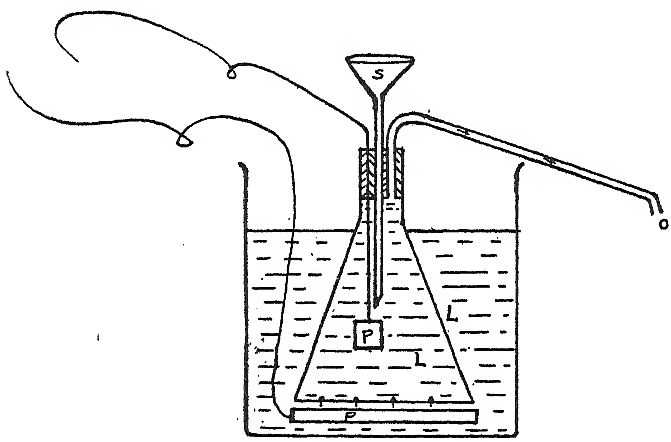



FIG. 21. Arrangement of electrode and solutions used in the experiment: *P*, platinum electrodes; *L*, lithium sulfate; *S*, funnel for adding new solution; *O*, overflow. Arrows at the base of the cell indicate direction of the electric current.

One of the cells was broken in order to determine the location of copper ferrocyanide membrane in the plate. The position was found to vary somewhat, but the general location was in the interior of the clay plate midway between the two surfaces.

## EXPERIMENTAL.

After the membranes had been in distilled water for five months their permeability was tested with molasses. It was found that the membranes did not hold the molasses entirely and that there was some exosmosis or movement of the molasses within the cell to the water outside the cell. This was thought to be due to a possible leak in the membranes, so the cells were again placed in copper sulfate

solution and potassium ferrocyanide added to the inside and allowed to remain for one week without the application of the electric current. At the end of that time the membranes were again tested and no exosmosis was detected.

The next step was to determine the behavior of some sugar solutions of known strength. In order to avoid the influence of a hydrostatic head, a scheme was devised by means of which the membranes were held in a vertical position and the surface of the liquid in the

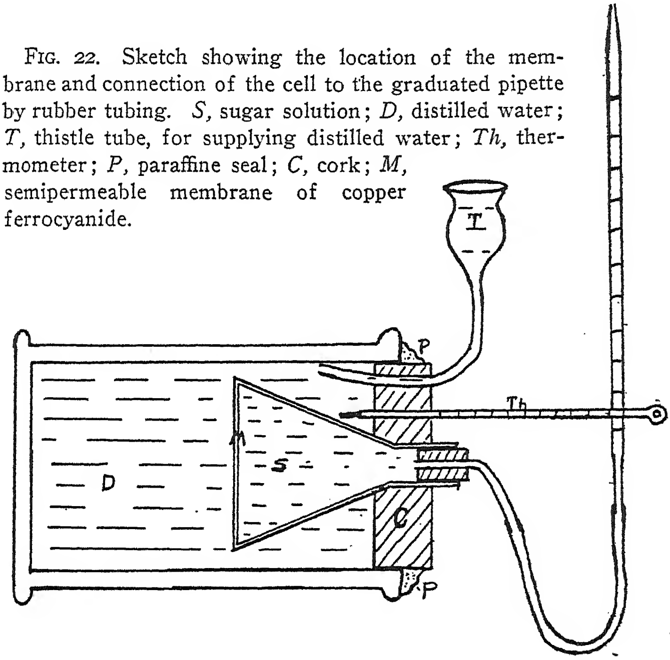



FIG. 22. Sketch showing the location of the membrane and connection of the cell to the graduated pipette by rubber tubing. *S*, sugar solution; *D*, distilled water; *T*, thistle tube, for supplying distilled water; *Th*, thermometer; *P*, paraffine seal; *C*, cork; *M*, semipermeable membrane of copper ferrocyanide.

tube kept level with the top of the distilled water in the outer container. The cells were supported in 10 × 15 cm. glass cylinders by means of a cork 4 cm. thick. This cork, which also served as a seal, was first boiled in paraffine and after insertion sealed over tight with the same material. Thistle tubes were provided in order that more water could be provided as it was taken up by osmosis through the semipermeable membranes of the cells. In this way the water was supplied to all parts of the membrane alike.

In figure 22, *S* is the sugar solution in the cell, the cell being connected to the graduated pipette by means of rubber tubing; *M* is the semipermeable membrane of copper ferrocyanide; *D* is the distilled water which is supplied through thistle tube *T; C* is the cork which

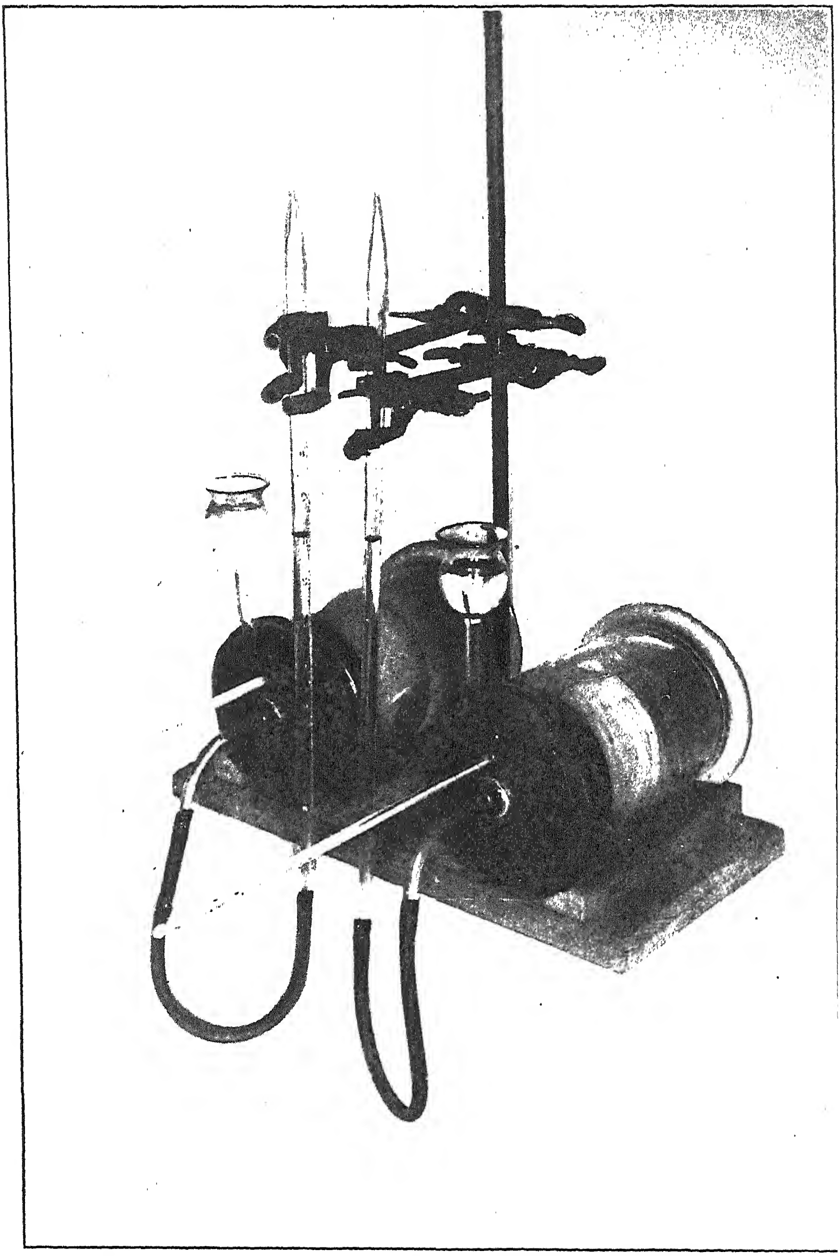
holds the cell in place; the cork is sealed over with paraffine, *P;* and *Th* is the thermometer. The method of setting up the cells is shown in Plate 8. The graduated pipettes are held in position by universal clamps, thus permitting the pipettes to be lowered as the solutions rise in them. The influence of a hydrostatic head is overcome in this way, for the water in the thistle tube and the solution in the pipettes can be kept on the same level.

The rates of rise for a 5, 10, and 15 percent sugar solution were obtained with the cells set up in the manner described above. Each cell was numbered and retained the same number throughout the series of experiments. Table 1 gives the rates of rise of the 5, 10, and 15 percent solutions, the temperature at the time of each reading, and the hours that had elapsed since the time of the first reading.

TABLE 1.—*Rise of 5, 10, and 15 percent sugar solutions in cells with a semi-permeable membrane.*

RISE OF 5 PERCENT SOLUTION IN 95 HOURS.

| Time in hours. | Cell No. 1. | | | Cell No. 2. | | |
|---|---|---|---|---|---|---|
| | Temperature. | Readings on graduated pipette. | Rise. | Temperature. | Readings on graduated pipette. | Rise. |
| | *° C.* | *cc.* | *mm.* | *° C.* | *cc.* | *mm.* |
| 0 | 21 | 0 | 0 | 20 | 0 | 0 |
| 20 | 24 | .45 | 10 | 24 | 1.55 | 35.5 |
| 25 | 24 | .50 | 11.5 | 24 | 2.20 | 50.5 |
| 45 | 18 | .75 | 17.0 | 18 | 4.70 | 108.5 |
| 67 | 14 | 1.05 | 24.0 | 14 | 6.20 | 141.0 |
| 95 | 22 | 1.15 | 26.5 | Out top of 10 cc. pipette. | | |
| RISE OF 10 PERCENT SOLUTION IN 165 HOURS. | | | | | | |
| 0 | 27 | 0 | 0 | 27 | 0 | 0 |
| 16 | 19 | .20 | 4.0 | 19 | .50 | 11.5 |
| 21 | 22 | .45 | 10.0 | 22 | .90 | 20.5 |
| 38 | 22 | .95 | 22.0 | 21 | 1.70 | 39.0 |
| 64 | 10 | 1.15 | 26.5 | 11 | 2.20 | 50.5 |
| 92 | 21 | 1.95 | 46.0 | 21 | 3.40 | 78.5 |
| 118 | 20 | 2.45 | 57.0 | 20 | 4.25 | 98.0 |
| 142 | 17 | 2.80 | 64.5 | 18 | 4.90 | 113.0 |
| 165 | 21 | 3.35 | 77.0 | 22 | 5.90 | 136.0 |
| RISE OF 15 PERCENT SOLUTION IN 170 HOURS. | | | | | | |
| 0 | 25 | 0 | 0 | 25 | 0 | 0 |
| 24 | 23 | .65 | 15.0 | 21 | .65 | 15.0 |
| 32 | 24 | .95 | 22.0 | 24 | .95 | 22.0 |
| 48 | 22 | 1.45 | 33.0 | 21 | 1.40 | 32.0 |
| 58 | 20 | 1.70 | 39.0 | 20 | 1.70 | 39.0 |
| 75 | 22 | 2.30 | 53.0 | 21 | 2.35 | 54.0 |
| 82 | 23 | 2.60 | 60.0 | 22 | 2.70 | 61.0 |
| 96 | 20 | 2.90 | 69.0 | 19 | 3.10 | 72.0 |
| 121 | 21 | 3.70 | 88.5 | 20 | 4.10 | 86.0 |
| 145 | 17 | 4.25 | 99.0 | 17 | 4.70 | 110.0 |
| 170 | 19 | 5.00 | 117.0 | 20 | 5.05 | 118.0 |



The cells were set up in the manner here shown. The graduated pipettes were held in position by universal clamps, thus permitting them to be lowered as the solutions rose in them. The influence of a hydrostatic head was thus overcome.

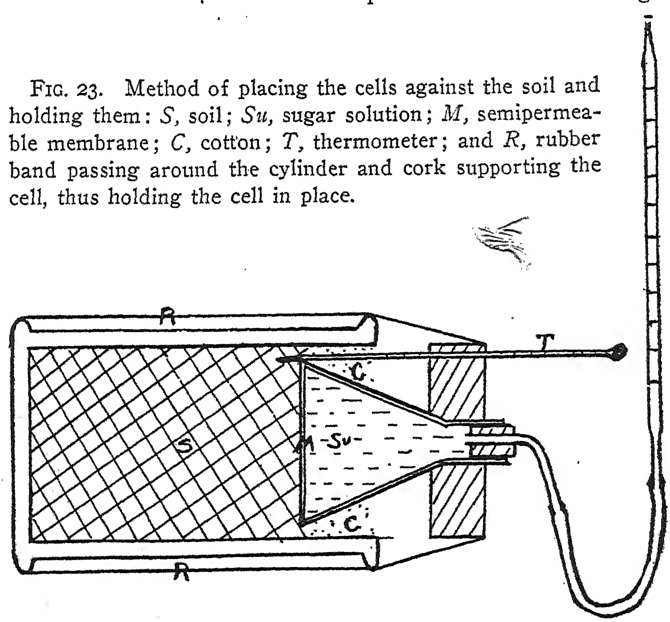
After the testing of the membranes with each of the 5, 10, and 15 percent sugar solutions, the cells were again placed in a solution of copper sulfate and a solution of potassium ferrocyanide added to the inside. They were allowed to remain in contact with the solutions for a period of one week before the next test was made. This was done to repair any leaks that might have developed in the membranes.

It will be noted from an inspection of Table 1 that the stronger the solution the more steady and uniform the rise; also, that the two membranes behave more nearly alike in the stronger solutions. This may be due in part to the ageing of the membranes and in part to the additional soaking and their consequent renewal in copper sulfate and potassium ferrocyanide solutions.

### Operation of the Membranes Against the Soil.

The types of soil used in this work were sandy loam, muck, and clay. The samples were taken from the surface 6 inches and put in the cylinders in as near a natural condition as possible, not being worked, dried, screened or otherwise manipulated. The cylinders were filled to within 4 cm. of the open end as shown in figure 23.

Fig. 23. Method of placing the cells against the soil and holding them: *S*, soil; *Su*, sugar solution; *M*, semipermeable membrane; *C*, cotton; *T*, thermometer; and *R*, rubber band passing around the cylinder and cork supporting the cell, thus holding the cell in place.




After the soil had been leveled off as smooth as possible, the bases of the cells were slightly moistened and placed against the soil, pressed firmly against the surface, and rotated several times to secure a good

contact. Two strong rubber bands (*R*, figure 23) were used to hold the cells in place and insure at all times a good contact with the soil. Cotton was placed over the exposed surface of the soil around the cells to avoid excessive evaporation (*C*, figure 23). A sample of the soil was taken at the time the cells were put in place for moisture determination.

Both cylinders were filled with sandy loam, muck, and clay, respectively, in the manner described and the apparatus set up as shown in figure 23. The results obtained from each of the soil types are given in Table 2. In working with the sandy loam and clay a 5 percent sugar solution was used, but for the muck a 2 percent solution was found to work better.

TABLE 2.—*Movement of a sugar solution against the solution contained in sandy loam, muck, and clay soils.*

SANDY LOAM CONTAINING 19 PERCENT MOISTURE.

| Time in hours. | Cell No. 1. | | | Cell No. 2. | | |
|---|---|---|---|---|---|---|
| | Temperature. | Readings on graduated pipette. | Rise. | Temperature. | Readings on graduated pipette. | Rise. |
| | ° *C.* | *cc.* | *mm.* | ° *C.* | *cc.* | *mm.* |
| 0 | 20 | 0 | 0 | 19 | 0 | 0 |
| 24 | 19 | 0 | 0 | 18 | 0 | 0 |
| 48 | 20 | 0 | 0 | 18 | 0 | 0 |
| 60 | 21 | .10 | 2.0 | 20 | .15 | 3.0 |
| 72 | 22 | .20 | 4.5 | 21 | .25 | 6.0 |
| 84 | 22 | .25 | 6.0 | 21 | .35 | 8.0 |
| 96 | 19 | .25 | 6.0 | 20 | .45 | 10.0 |
| 108 | 24 | .45 | 10.0 | 23 | .65 | 15.0 |

MUCK SOIL CONTAINING 34.19 PERCENT MOISTURE.

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 18 | 0 | 0 | 18 | 0 | 0 |
| 17 | 18 | − .3 | − 7.0 | 20 | − .7 | −16.0 |
| 41 | 20 | − .4 | − 9.0 | 20 | − .9 | −20.0 |
| 65 | 22 | 2.2 | 50.5 | 22 | −1.0 | −22.5 |
| 89 | | Out top 10 c.c. pipette | | 24 | .2 | 4.5 |
| 113 | | ........ | | | Out top 10 c.c. pipette | |

CLAY SOIL CONTAINING 35.64 PERCENT MOISTURE.

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 25 | 0 | 0 | 25 | 0 | 0 |
| 24 | 22 | 3.10 | 72.5 | 22 | 3.70 | 85.5 |
| 48 | 23 | 8.70 | 201.0 | | Out top 10 c.c. pipette | |
| 60 | | Out top 10 c.c. pipette | | | ........ | |

## DISCUSSION.

While the above data are not very extensive and are comparatively simple in many respects, they present a few problems in a field in

which little, if any, work has been done. It has long been known that soil moisture responds to two forces, viz., gravitational pull and capillary attraction. In addition to these two forces a third force manifests itself, a force that is the result of the osmotic pressure of the soil solution. In this work the effect of the gravitational pull was overcome by placing the membranes in a vertical position and that of the capillary attraction prevented by reducing the surface exposed in the graduated tubes.

Work previously done with animal bladders or other semipermeable membranes show that when two solutions of different concentrations are separated by such membranes the more dilute solution always moves toward the solution of greater concentration. From Table 2 it appears that the soil solution is of less concentration than the sugar solutions used, because there has been a movement of the soil solution into the sugar solution.

It will be noticed that the different kinds of soil containing different amounts of moisture act differently toward the sugar solutions. Referring to Table 2, it will be noticed that the sandy loam seems to be able to withstand the pull of a 5 percent sugar solution better than the others. Whether this is due to the texture of the soil or to the amount and concentration of the moisture present is a problem in itself and can not be settled here, but it would seem that with less moisture present there would be greater concentration of the solutes in the soil and hence greater resistance to the osmotic pull of the sugar solution.

The muck contained about twice as much moisture as the sandy loam and in working with it the rise of a 5 percent sugar solution in the pipettes was so rapid that no satisfactory readings for a period of time could be obtained. To overcome this difficulty a 2 percent solution was used. From Table 2 it will be noticed that there was some exosmosis at first, which was followed by a very rapid rise. The exosmosis was probably due to a poor contact of the cell with the soil. Later, the cell became firmed against the soil and the rapid rise of the sugar solution followed. If it is taken into consideration that with muck a 2 percent sugar solution was employed, while with sandy loam and clay a 5 percent solution was used, it will appear that the soil solution in muck is less concentrated than that of the sandy loam or clay, for there would be a greater rise of the sugar solution in the pipettes. This is what might be expected *a priori*, since muck is loose, porous, and spongy in its makeup and hence contains a greater amount of moisture than the other soils, and this

greater amount of moisture will make the soil solution less concentrated.

That soil solutions are capable of developing osmotic pressure is not to be doubted. This work, though limited, was directed toward the development of a method by which the magnitude of the osmotic pressure of soil solutions might be measured. Just what is the strength of these soil solutions in terms of a sugar solution? The author hoped to be able to determine this by balancing a sugar solution of known strength on one side of a semipermeable membrane against the soil containing a soil solution of unknown strength placed against the other side. When a sugar solution of known strength has been found that will give neither osmotic nor exosmotic movement on placing the membranes in contact with the soil, then the strength of the soil solution would be known. However, the necessity for frequent soaking and repairing of the membranes limited the time for experimental work and all that can be said is that the concentration of the soil solution (measured in terms of osmotic pressure) in sandy loam and clay appears to be below that of a 5 percent sugar solution and that of muck below that of a 2 percent solution.

## THE RELATION OF THE VIGOR OF THE CORN PLANT TO YIELD.[1]

A. E. Grantham.

Low yields of corn are generally attributed to poor seed, insufficient plant food, careless cultivation, or to a combination of these factors, but another condition in the development of a field of corn may affect the yield. It is well known to close observers that considerable variation exists in the size and vigor of the corn plants under average conditions in the field. These differences are more noticeable when the plants are only a few weeks old; as the crop develops they are more or less obscured. To what extent this variation in the size of the plant affects the yield has not been seriously considered or reported on. It is generally assumed, however, that the less vigorous plants fall below the average in yield. Not long ago the writer had the opportunity of observing the behavior of a large number of plants through the growing season and of finally determining the actual yield.

[1] Contribution from the Delaware Agricultural Experiment Station, Newark, Del. Received for publication May 29, 1917.

During the latter half of June most corn fields present a condition somewhat as follows. If the corn is planted in hills, one of the two stalks often will be fairly vigorous and thrifty while its companion plant will be only half to two-thirds the size of the larger. It will surprise anyone to note the proportion of hills of corn in the average field that present this condition. The writer determined to follow up the development and maturity of a number of hills of this character in a field where the soil conditions were uniform and marked a number of hills in which a weak stalk was growing along with a vigorous one. The corn under observation was planted in hills 42 inches apart each way, two plants to the hill. Care was taken in selecting the hills that they were located where the stand was uniform with no hills missing. Of the first 50 hills selected in which there was a marked difference in the size and vigor of the two plants the weaker stalk was removed, leaving the more vigorous plant. In another 50 hills the strong stalk was removed and the weak one left. All of the hills marked were well scattered, no two being adjacent. The height of the remaining stalk was taken at the time the hill was thinned and the plant marked with a small stake bearing a number. This was done for each of the hundred plants under observation. The object of thinning was to eliminate any undue influence of one plant upon the other. At intervals of about eight days the staked plants were measured to determine the rate of growth. These measurements were continued until September 18. The date of tasseling for each plant was likewise noted. The relative rate of growth for the two sets of plants from June 25 to September 18 is given in Table 1.

TABLE 1.—*Rate of growth in inches of strong and of weak stalks of corn measured on various dates from June 25 to September 18.*

| Date. | Height in inches. | | | | Difference in height. | |
|---|---|---|---|---|---|---|
| | Weak stalks. | | Vigorous stalks. | | | |
| | Average. | Gain. | Average. | Gain. | Inches. | Percent. |
| June 25 | 4.7 | — | 9.2 | — | 4.5 | 95 |
| July 3 | 9.4 | 4.7 | 18.1 | 8.9 | 8.7 | 92 |
| July 12 | 20.6 | 11.2 | 31.7 | 13.6 | 11.1 | 53 |
| July 20 | 26.9 | 6.3 | 42.2 | 10.5 | 15.3 | 56 |
| July 27 | 35.0 | 8.1 | 56.4 | 14.2 | 21.4 | 61 |
| Aug. 5 | 52.2 | 17.2 | 76.5 | 20.1 | 23.3 | 44 |
| Aug. 11 | 66.5 | 14.3 | 87.9 | 11.4 | 21.4 | 32 |
| Aug. 19 | 76.7 | 10.2 | 92.3 | 4.4 | 15.6 | 20 |
| Sept. 18 | 98.0 | 21.3 | 107.3 | 15.0 | 9.3 | 9 |

Table 1 shows that there was considerable difference in the aver-

age height of the two sets of plants at the beginning and at the end of the growing period. The extreme difference in height, 23.4 inches, was on August 5, the date the more vigorous plants came into tassel. The average date of tasseling of the weaker plants was August 12, a difference of nine days in the time of tasseling. While there was 95 percent difference in height on July 25, there was but 9 percent difference on September 18. This difference in the height of the mature plants is so small that it would hardly be noticed by the casual observer.

When the corn had matured each set of plants was harvested individually. At the proper time for husking the two lots were husked and weighed separately. The weight of each individual ear was taken and the corn stored until thoroughly dry for shelling. The average weights of ears from plants tasseling at different dates are given in Table 2. It will be noted that the weight of the ears from the strong plants varies from 277 to 338 grams and from the weak plants from 60 to 283 grams.

TABLE 2.—*The average weight at husking time of ears from strong and from weak plants tasseling at various dates.*

| Dates of tasseling. | Strong plants. | | Weak plants. | |
|---|---|---|---|---|
| | No. of ears. | Average weight. | No. of ears. | Average weight. |
| | | *Grams.* | | *Grams.* |
| July 27 | 4 | 291 | | |
| August 3 | 22 | 338 | 4 | 283 |
| August 5 | 8 | 315 | 2 | 165 |
| August 7 | 6 | 277 | 8 | 280 |
| August 9 | 1 | 305 | 3 | 113 |
| August 11 | 5 | 310 | 11 | 151 |
| August 13 | 1 | 290 | 8 | 163 |
| August 17 | | | 7 | 142 |
| August 19 | | | 2 | 60 |
| August 21 | | | 3 | 101 |
| Total or average | 47 | 309 | 48 | 177 |

The average weight of the ears from the strong plants is 309 grams; from the weak plants, 177 grams, a difference of 74 percent. The table also shows that nearly half of the weak plants tasseled after Aug. 11, while only one of the stronger plants came into tassel after that date.

In Table 3 the distribution of the population of each group of ears with respect to weight is shown.

TABLE 3.—*Distribution of the population of ears from strong and from weak plants according to weight.*

| Weight of ear, grams. | Number of ears. | | Weight of ear, grams. | Number of ears. | |
|---|---|---|---|---|---|
| | Strong stalks. | Weak stalks. | | Strong stalks. | Weak stalks. |
| 0–50........ | 0 | 5 | 300–350...... | 11 | 4 |
| 50–100...... | 0 | 5 | 350–400...... | 8 | 1 |
| 100–150..... | 2 | 10 | 400–450...... | 2 | 0 |
| 150–200..... | 4 | 9 | 450–500...... | 3 | 0 |
| 200–250..... | 7 | 8 | 500–550...... | 1 | 0 |
| 250–300..... | 8 | 6 | | | |

Table 3 shows that the strong plants produced no ears under 100 grams in weight. On the other hand, there were 10 ears from the weak stalks that weighed less than 100 grams. More than half of the ears from the strong stalks weighed over 300 grams, while two-thirds of the ears from the weak stalks weighed less than 200 grams. The yield of dried shelled grain was 221.7 and 109.6 grams from the strong and weak plants, respectively; the weight of cob, 41.7 and 38.8 grams. The strong plants had 19 percent of cob and the weak, 24 percent. The yield of shelled grain from the strong plants was 102 percent larger than from the weak.

The results of this very brief study indicate that the weaker plants in a population of corn are much below the average in yield. The stand of plants in a field may be perfect and yet produce only an ordinary crop. The weak plants may be the result of environment, but not in this test, as each weak stalk had at the beginning a strong companion stalk. The weakness would appear to be inherited, the result of a lack of vigor on the part of the kernel. This inference naturally leads to the question of thinning corn. If care is used in thinning so that only the more vigorous plants are left in the hill a considerable advance in yield may be expected over haphazard selection. It may also be advisable to plant several kernels to the hill so that a wider opportunity for selecting the stronger plants may be offered. Further work along this line must be undertaken to determine fully the extent of these differences and the methods which may be employed to obtain the most vigorous plants.

# THE EFFECT OF DIFFERENT ROTATION SYSTEMS AND OF FERTILIZERS ON THE PROTEIN CONTENT OF OATS.[1]

R. W. THATCHER and A. C. ARNY.

## INTRODUCTION.

The Farm Crops Section of the Division of Agronomy and Farm Management of the Minnesota Agricultural Experiment Station has under way a series of plot studies of various crop rotations, both with and without the application of manure and of various forms of commercial fertilizers. These plots serve very well for a study of the effect of the soil treatment and of clover in the rotation upon the chemical composition of the succeeding crops. Several different lines of study of this sort are in progress. The present paper deals with certain results which have been obtained with oats.

Samples of the crop of oats from each of the several plots involved in the study were taken each year to the chemical laboratory and the percentage of dry matter and of protein which they contained determined in the usual manner. No field data other than the plot numbers accompanied the samples and it was not until the analytical figures were finally compiled for record that the regular effect of the various plot treatments upon the protein content of the oats was discovered. This effect is so definite and so striking that it seems desirable to publish the results at the present time, although the studies will be continued over a considerably longer period of years.

There are a few previous reports of results of analyses of oats to show the effect of fertilizers used upon the composition of the grain, but they are generally the results of a single season's tests, often with inconclusive results. Woods[2] found an apparent increase in protein content of both grain and straw with increased application of nitrogen in the fertilizer. Weibull,[3] using the composition of the crop as an index for fertilizer requirement of the soil, concluded that since he found slightly increased percentages of nitrogen in the grain and

[1] Published with the approval of the Director as Paper No. 72 of the Journal Series of the Minnesota Agricultural Experiment Station. Received for publication July 2, 1917.

[2] Woods, C. D. Effects of different fertilizers upon the composition of oats and straw. *In* Conn. Storrs Agr. Expt. Sta. Rpt. for 1892, p. 47–56.

[3] Weibull, M. Cooperative fertilizer experiments in Malmöhus County, Sweden, 1902. *Abs. in* Expt. Sta. Rec., 15: 570. 1903.

of potash in the straw from plots which were fertilized with those particular elements and no consistent increase in phosphoric acid in the grain from plots to which phosphate fertilizers had been added, the soils were in need of nitrogen and potassium, but not of phosphorus. Pingree,[4] as a result of studies of oats grown in 1904, found that where nitrogen was applied alone a larger proportion of protein in the dry matter of the entire plant was produced than in any other of the soil treatments used, the proportion being distinctly less in the crop on the unfertilized plot, still lower when potassium alone was used, and lowest of all whenever phosphoric acid was used (even in a complete fertilizer). Tretiakow,[5] in a single experiment, found that an application of barnyard manure increased the protein content of oats from 11.38 percent to 12.81 percent.

Lipman[6] studied the effect of the application of potassium sulfate and of sodium nitrate to oats grown alone and grown with peas in large galvanized iron cylinders in the open field and in pots in the greenhouse, and of other combinations of legume and non-legume under varying conditions, and came to the conclusion that

1. Under favorable conditions non-legumes associated with legumes may secure large amounts of nitrogen from the latter, even though this may not be indicated by an increased proportion of nitrogen in the dry matter of the non-legume.

2. When sodium nitrate is applied to such crop mixtures, the non-legumes gain an advantage in the competition for moisture, light and plant-food, and the growth of the legume is depressed. The latter contains not only less of dry matter and nitrogen, but may possess a smaller proportion of nitrogen in the dry matter.

Lyon and Bizzell[7] have noted an increased protein content of timothy when grown in association with alfalfa or with clover and of oats when grown with peas as compared with that of the grass or cereal when grown alone on adjacent plots in the same season.

None of these studies, however, have dealt with the effect of a legume in the rotation upon the protein content of other crops grown in intervening years upon the same plot. So far as we are aware,

[4] Pingree, M. H. The influence of nitrogenous, phosphatic and potassic fertilizers upon the percentage of nitrogen and mineral constituents of the oat plant. *In* Penn. Agr. Expt. Sta. Rpt., 1906, p. 43–53.

[5] Tretiakow, S. S. F. Influence of mode of cultivation on the chemical composition of cereals. *Abs. in* Expt. Sta. Record, 34 (1916), p. 230.

[6] Lipman, J. G. The associative growth of legumes and non-legumes. N. J. Agr. Expt. Sta. Bul. 253. 1912.

[7] Lyon, T. L., and Bizzell, J. A. A heretofore unnoted benefit from the growth of legumes. New York (Cornell) Agr. Expt. Sta. Bul. 294. 1911.

the data presented below are the first to be presented which deal with this phase of the problem.

The crops from which the samples were taken for our analyses were in regular rotation series. Hence, with the exception of the plot sown to oats continuously, the crop which had received the given treatment in any given year grew upon a different plot than in the preceding year or, in the 4-year and 5-year rotations, in any of the previous years. This reduces to a minimum the possibility of the observed effects being due to soil differences or to accumulations from previous soil treatments. We believe, therefore, that the results here presented afford conclusive evidence on the points in question.

The particular cultural and soil treatments the effects of which are considered in this paper are briefly described below. In all of the systems except where oats are grown continuously the crops are grown successively on as many plots as there are crops in the rotation. The same variety of oats was used for the entire series and the rate and date of seeding, method of harvesting, etc., were uniform for the series each year.

## Rotation Plots.

*Continuous Oats.*—This plot has been seeded to oats each spring since 1909. Manure is applied to the plot at the rate of 6 tons per acre every third year in the autumn preceding the preparation of the seed bed for the next year's crop. The last application was in the autumn of 1915.

*Two-year Rotation, Oats and Wheat.*—Treatment the same as for the plot on which oats are grown continuously, except that oats and wheat are alternated on two plots.

*Two-year Rotation, Oats and Corn.*—Same as preceding except alternate plantings of corn and oats.

*Three-year Rotation, No Manure.*—Corn, oats, and clover are seeded in rotation, with no manurial treatment.

*Three-year Rotation, "Model Rotation."*—Same as preceding plot, except that manure is applied the autumn previous to the planting of the corn at the rate of 6 tons per acre.

*Four-year Rotation.*—Corn, oats, wheat, and clover are seeded in rotation, manure being applied the autumn preceding the corn at the rate of 8 tons per acre.

*Five-year Rotation.*—Corn, oats, wheat, and clover and timothy hay are grown in rotation and the plot pastured during the fifth year. Manure is applied the autumn preceding the corn at the rate of 10 tons per acre.

### Fertilizer Plots.

All of these plots are in a 3-year rotation of corn, oats, and clover. The fertilizer is applied annually. The different fertilizers are purchased and applied separately. The phosphates and potash are applied at seeding time. The nitrate is applied after the grain and corn are up. The following are the kinds and amounts of fertilizer used.

*Commercial Fertilizer Only.*—Two hundred and fifty pounds of acid phosphate and one hundred pounds of muriate of potash per acre are applied, half to the oats and half to the corn at the time the seed bed is prepared. After the grain is up 300 pounds of nitrate of soda per acre are applied, half to each crop.

*Manure and Commercial Fertilizer.*—Manure at the rate of 6 tons per acre and the same commercial fertilizer as used on the preceding plot are applied.

*Manure and Nitrate of Soda.*—Six tons of manure per acre are applied to the corn each year and in addition 320 pounds of nitrate of soda per acre, half to the oats and half to the corn.

*Manure and Muriate of Potash.*—Six tons of manure per acre are applied to the corn each year and in addition 200 pounds of muriate of potash per acre, half to the oats and half to the corn.

*Manure and Raw Rock Phosphate.*—Six tons of manure and 1,000 pounds of raw rock phosphate per acre are applied to the corn each year.

*Manure and Acid Phosphate.*—Six tons of manure per acre are applied to the corn and in addition 400 pounds of acid phosphate per acre, half to the oats and half to the corn.

### Results of Analyses.

The results of the analyses of the oat crops from the various plots are shown in Tables 1 and 2.

These results clearly show a definite effect of the rotation system upon the chemical composition of the oat crop. The short rotations, with no clover or intertilled crop to provide for summer cultivation to the land, uniformly yield oats with a low percentage of protein. The 3-year rotations, with clover and either with or without manuring, with at least one corn crop to provide summer cultivation, give oats of medium protein content; and the longer rotations, with clover or with clover and pasture, yield oats of high protein content.

The results presented in Table 2 show a definite correlation between the protein content of the oat grain and the fertilizer treatment. The plots receiving fertilizers which contain nitrogen invari-

TABLE 1.—*Effect of differential rotation systems upon the protein contents of oats, expressed as percentage of protein in the dry matter.*

| Rotation. | Manure applied. | Percentage of protein in dry matter. | | | |
|---|---|---|---|---|---|
| | | 1914. | 1915. | 1916. | Average. |
| None, continuous oats | 6 tons per acre each 3d year | 12.94 | 11.96 | 13.02 | 12.64 |
| 2-year, oats and wheat | do. | 12.63 | 12.17 | 12.73 | 12.51 |
| 2-year, oats and corn | do. | 13.25 | 11.95 | 13.13 | 12.78 |
| 3-year, oats, clover, corn | None | 14.00 | 14.66 | 15.46 | 14.71 |
| 3-year, oats, clover, corn | 6 tons per acre, preceding corn | 14.63 | 13.45 | 14.92 | 14.33 |
| 4-year, wheat, clover, corn, oats | 8 tons per acre, preceding corn | 15.25 | 15.73 | 14.89 | 15.29 |
| 5-year, wheat, clover, pasture, corn, oats | 10 tons per acre, preceding corn | 15.88 | 14.49 | 15.05 | 15.14 |

TABLE 2.—*Effect of different fertilizations upon the protein content of oats grown in a 3-year rotation of oats, clover, and corn, expressed as percentages of protein in the dry matter.*

| Fertilizer used. | Percentage of protein in dry matter. | | | | |
|---|---|---|---|---|---|
| | 1913. | 1914. | 1915. | 1916. | Average. |
| None (check plot) | 14.56 | 14.63 | 13.09 | 14.92 | 14.30 |
| Commercial only | 16.00 | 15.31 | 13.57 | 16.10 | 15.24 |
| Manure + commercial | | 14.69 | 15.00 | 15.57 | 15.09 |
| Manure + nitrate of soda | 15.13 | 15.88 | 16.14 | 15.80 | 15.74 |
| Manure + muriate of potash | 13.81 | 13.69 | 12.06 | 14.06 | 13.40 |
| Manure + raw rock phosphate | 14.12 | 13.69 | 14.06 | 14.76 | 14.16 |
| Manure + acid phosphate | 14.31 | 13.94 | 15.10 | 14.40 | 14.44 |

ably produce grain having a higher protein content than that from the plots which received any other treatment. The single sample having the highest percentage of protein and the highest average for the 4-year period resulted from the use of nitrate of soda. The complete fertilizer contained enough readily available nitrogen to produce nearly the same effect upon the composition of the oats as the sodium nitrate alone. The potash fertilizer produced oats which were slightly lower in protein content than those from the check plots in every one of the four years. The phosphate fertilizers did not materially change the protein content of the grain, that from the treated plots being sometimes slightly higher and sometimes slightly lower than that from the check plots, with the average protein content practically identical in the check, the raw rock phosphate and the acid phosphate plots.

# AGRONOMIC AFFAIRS

## THE TENTH ANNUAL MEETING.

The tenth annual meeting of the Society will be held in Washington, D. C., on the date tentatively announced in the September number (November 12 and 13). A number of titles for papers have already been submitted, but there is still room on the program for a few more. Those who expect to attend and to present papers are urged to notify the Secretary at once, so that the full program may be printed and mailed to members in advance of the meeting.

## MEMBERSHIP CHANGES.

The membership reported in the last number was 655. Since that time 6 new members have been added and 8 have resigned, making the present membership 653. The names and addresses of the new members, the names of the members resigned, and such changes of address as have been reported to the Secretary follow.

### New Members.

Foersterling, H., 380 High St., Perth Amboy, N. J.
Gray, W. F., County Agent, Woodward, Okla.
Jackson, L. D., Western Canada Flour Mills Co., Winnipeg, Man.
Metzger, J. E., College Park, Md.
Murray, James, Macdonald College, Quebec, Canada.
Pittman, D. W., Agr. Expt. Sta., Logan, Utah.

### Members Resigned.

Craig, C. E.
Garren, G. M.
Koeber, James.
McQuarrie, C. K.
Schick, Geo. M., jr.
Smith, Herbert G.
Voigt, Edwin.
Wehrle, L. P.

### Changes of Address.

Andrew, Myron E., Station A, Ames, Iowa.
Bell, N. Eric, Greenville, Ala.
Bledsoe, R. Page, 210 Elizabeth St., Charleston, W. Va.
Bryant, Ray, Frederick, Okla.
Cutler, G. H., University of Alberta, Edmonton South, Alta., Canada.
Hill, Pope R., Toccoa, Ga.

KEMP, A. R., Bridgeport, Ill.
MACFARLANE, WALLACE, University of Arizona, Tucson, Ariz.
ROBERTSON, R. B., R. R. No. 2, Box 5, Vinson, Okla.
SCHUER, HENRY W., 249 W. 10th St., Columbus, Ohio.
SOUTHWICK, EVERETT F., 208 Lowell St., Peabody, Mass.
STEWART, GEO., Agr. Expt. Sta., Logan, Utah.
SUDDATH, R. O., Auburn, Lee Co., Ala.
WILLARD, C. J., Dept. of Farm Crops, O. S. U., Columbus, Ohio.

## NOTES AND NEWS.

W. A. Albrecht, formerly of the Missouri university and station, is now acting head of the department of agronomy in the University of Wyoming.

W. W. Baer, assistant chemist of the New York State station, has entered the U. S. naval service.

J. F. Barker, agronomist of the New York State station, has been placed in charge of extension work in agronomy at Ohio State University, and has been succeeded at Geneva by R. C. Collison, formerly associate chemist. Mr. Collison has been granted a year's leave of absence for study.

W. L. Carlyle, formerly director of the Oklahoma station, is now in charge of a 4,000-acre farm in the Canadian Northwest.

D. A. Coleman has been appointed assistant agronomist of the New Jersey college and station.

Frank R. Curtis has been appointed director of the Canebrake station at Uniontown, Ala. L. H. Moore, the former director, will remain as assistant director.

G. H. Cutler, professor of cereal husbandry in the University of Saskatchewan, is now professor of field husbandry in the University of Alberta.

A. W. Gilbert, who spent the past year in graduate study in rural economics at Harvard University, has resigned his position as professor of plant breeding in Cornell University and is now connected with the Boston Chamber of Commerce.

J. D. Harper, assistant in crops extension in Purdue University, is now county agent in Laporte County, Ind.

Ralph D. Hetzel, director of extension in Oregon, has accepted the presidency of the New Hampshire Agricultural College and has entered on his duties. He has been succeeded in Oregon by O. D. Center, formerly director of extension in Idaho.

E. R. Hodgson, associate agronomist at the Virginia college and station, has become specialist in agronomy in the Virginia extension service, and has been succeeded in the college and station by T. K. Wolfe, formerly assistant agronomist.

R. R. Hudelson, assistant professor of soils in the University of Missouri, is absent on a year's leave and is enrolled in the Reserve Officers Training Camp at Fort Sheridan, Ill.

R. A. Kinniard has been promoted from extension instructor to extension assistant professor of soils in the University of Missouri.

M. W. Kirkpatrick, formerly superintendent of the Dodge City, Kans., substation, has succeeded C. E. Cassel, resigned, as superintendent of the Tribune substation in the same State.

E. H. Lindley, professor of philosophy in the University of Indiana, has been elected president of the University of Idaho and has entered on his duties.

Franklin L. McVey, president of the University of North Dakota, has been elected president of the University of Kentucky.

Wallace Macfarlane, who for the past year has been assistant agronomist in charge of soils work at the Oklahoma station, is now agronomist of the University of Arizona.

C. E. Myers has been promoted to associate professor of plant breeding and C. F. Noll and J. W. White to associate professors of experimental agronomy in the Pennsylvania college and station.

J. S. Owens has been appointed assistant in experimental agronomy at the Pennsylvania station.

T. S. Parsons, agronomist of the Wyoming university and station, has been granted a year's leave of absence for graduate work at the University of Wisconsin.

Joe Robinson has been appointed assistant agronomist in the Wyoming university and station, succeeding P. T. Meyers, resigned to become county agent for Campbell County, Wyo.

Henry W. Schuer and C. J. Willard, the latter from the University of Illinois, have been added to the instructional force in farm crops in Ohio State University.

George Stewart, who spent the past year in graduate work in Cornell University, has been made assistant professor of agronomy and assistant agronomist in the Utah college and station.

C. A. Thompson has been appointed assistant in soils and O. E. Barbee assistant in farm crops at the Washington station.

Donald K. Tressler, formerly assistant in agricultural chemistry in the Cornell station, is now with the U. S. Bureau of Soils.

R. G. Wiggans, assistant professor of farm crops in the Ohio State University during the past year, is again associated with the farm crops department of Cornell University.

C. G. Woodbury, horticulturist, has been elected director of the Indiana station.

## Third Interstate Cereal Conference.

The third Interstate Cereal Conference was held at Kansas City, Mo., June 12–14, 1917. The attendance was about 60, representing 8 States, 8 offices of the U. S. Department of Agriculture, the Minnesota and Kansas grain inspection departments, several commercial concerns, and the Southwestern farm and trade press. A wide range of topics was discussed, though much of the time was devoted to means of increasing and conserving cereals during the present emergency. A part of the third day of the conference was spent in the inspection of mills, elevators, and other points of interest in Kansas City. A majority of those in attendance visited the Kansas station and college at Manhattan on June 15 and a considerable number continued the trip to include the branch station at Hays on the following day.

## Conference of Western Agronomists.

The second annual conference of agronomic workers in the eleven western States was held July 31 and August 1 and 2 at Moscow, Idaho, and Pullman, Wash. The first day's sessions and that on the morning of the second day were held at Moscow, and the remaining ones at Pullman. Seven States and several offices of the U. S. Department of Agriculture were represented, the State and departmental forces including men from 15 stations. The program included discussions of fallowing, rotations, tillage methods, the use of irrigation water, the nitrogen supply, the distribution of superior seed stocks, marketing, adaptation of varieties, the use of new crops, interstate cooperation in experimentation, and other topics of interest to agronomic workers. The next conference will be held at Corvallis, Ore., on a date to be decided by the executive committee, of which Gorge R. Hyslop is the local representative.

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## WHY CEREALS WINTERKILL.[1]


S. C. SALMON.


### INTRODUCTION.

Winterkilling has been investigated as little as any of the important phases of cereal crop production. Practically no experiments to determine its causes have been conducted in the United States and only a few in foreign countries. The status of present knowledge depends largely on general observation and a few experiments with other plants, chiefly vegetables and fruits.

Where winter cereals can be successfully grown they usually yield from a few bushels more than to several times as much as spring varieties. There are other advantages, such as early maturity, distribution of labor, and condition of the ground for seeding. Only about one fourth of the world's wheat crop is sown in the fall, however, and a much smaller proportion of oats and barley. The winter varieties of these grains are not sown mainly because of their inability to survive the severe winters of the principal grain-growing areas of the world.

This paper is intended to suggest some probable causes of winterkilling, but especially to bring together the results of experiments and general observation as a basis for further investigations.

### CAUSES OF WINTERKILLING.

The probable causes of winterkilling may, for convenience, be grouped under four heads, though in some cases the boundaries over-


[1] Contribution from the Kansas Agricultural Experiment Station, Manhattan, Kans. Received for publication May 7, 1917.

lap. They are (1) heaving, (2) smothering, (3) physiological drought, and (4) direct effect of low temperature on the plant tissue and protoplasm.

### HEAVING.

Heaving is one of the most common causes. It occurs especially on poorly drained soils in humid areas and is believed to be more common on heavy than on light soils. It occurs usually in the spring and is due to alternate freezing and thawing, which expands the soil and then allows it to contract. The plants are lifted from the soil and the roots are broken and exposed to the air. Heaving is a common cause of winterkilling in the eastern half of the United States.

No method is known for preventing heaving. Drainage of wet areas will aid but will not entirely prevent heaving, since it occurs on soils that are normally well drained. Well-prepared ground, timely seeding, and other conditions which promote a healthy growth and strong roots are important.

Montgomery (43)[2] found that rolling early in the spring where heaving had taken place prevented much of the injury that would otherwise occur.

Newman and Pickett (47) report that in South Carolina plants from deeply sown seed are more likely to be injured than are those from shallow planting. The explanation is as follows: The soil seldom freezes deeper than 3 inches. If the grain is sown deep, the seminal roots are below the frost line and the coronal roots above. When the ground freezes, the upper part of the plant together with the coronal roots is lifted with the surface soil, while the seminal roots are held below. As a result the connection between the two sets of roots is broken. If the seed is covered shallow, however, both will be in the frozen soil and will be lifted together.

Wollny (78) states that plants from shallow planting are less likely to be injured than from deep planting, but he attributes the difference to more vigorous plants in the former case.

Wright (79) in experiments conducted in Indiana, found a decidedly greater survival from seeding 1½ inches deep than from seeding either three fourths of an inch or from 3 to 4 inches deep.

McClelland (36) found that winter oats sown in deep furrows in Georgia were protected from injury due to heaving by dirt from the ridges falling about the crowns of the plant. Similar results were secured by the writer at the Kansas station (57).

[2] Figures in parentheses refer to papers similarly numbered in the bibliography on page 377.

### SMOTHERING.

Smothering is believed to be a frequent cause of injury when the grain is covered with an ice sheet or very deep snow. Whether the plants die from lack of air, as implied, or from some other cause seems never to have been determined.

Watson and Miller (72) note that varieties of wheat at the Pennsylvania station were badly damaged by an ice sheet during early March, 1904. Nearly all the wheat so covered was killed. The injury was attributed to smothering. Similar damage was noted by Noll (49) for the winter of 1909–10. The ice sheet in this case was several inches thick. It occurred earlier in the season and remained for a longer period, i. e., during most of January and February. The injury was less, however, than in 1904. There was little relation between variety and extent of injury except that the Turkey and a spring wheat sown in the fall suffered more than the others. Timothy sown with the wheat was injured less than the wheat.

Winter grains at Manhattan, Kans., and elsewhere in Kansas were badly damaged during the winter of 1909–10. The injury was attributed to an ice sheet formed by refreezing of melted snow. The survival was greatest south or east of a hedge, stone wall, or other obstruction to the wind. In these locations the snow which fell in midwinter did not change to ice so soon, the damage being greatest where the ice formed earliest. Early sown wheat survived better than late sown and apparently those varieties survived best which had the densest growth of leaves.

In 1916 an ice sheet from half to 1½ or more inches thick occurred at Manhattan, Kans., without apparent injury to any winter grain. This ice sheet was caused by a storm of sleet and rain, which froze nearly as rapidly as it fell. The surface of the ground, the sleet, and the melted snow surrounding the plants was frozen in a solid mass. The storm occurred January 25 and the ice remained until February 10. Considerable injury was reported in the northeastern part of the state, where the ice was thicker.

Sinz (68), among other observations relating to winterkilling of cereals at Goettingen, noted that an excessive snow covering may suffocate the plants.

Waldron (71) says that in northern Michigan wheat is often severely injured by snow, and that in Hungary a continuous snow covering upon the winter wheat is considered injurious. If snow crusts are formed they are broken by stock driven over the fields. He attributed a part of the injury to wheat at the Dickinson (N. Dak.) substation in 1910 to smothering because of deep snow.

Wright (79) sprayed plots of wheat in February with a fine spray of water when the air temperature was —12° to —15° C. When the water was frozen the operation was repeated until the blades of the plants and the surface of the ground were completely covered with ice. This ice remained on about three days. When it had thawed the grain was found to be seriously damaged and in the spring even the roots were dead. A microscopic examination of the leaves showed that the cellular structure had been decidedly disarranged. In many places the epidermis was entirely separated from the underlying cells, but the most evident effect was the disunion of the cells. In another experiment plants entirely submerged in water and others with their roots only submerged were frozen for 48 hours. Those entirely submerged were the more seriously damaged. A microscopic examination of the tissue showed conditions similar to those found in the first experiment.

### PHYSIOLOGICAL DROUGHT.

Physiological drought has never been proved to be a cause of winterkilling of cereal crops, but has long been regarded as a cause of injury to shrubs and trees. A cold soil and especially a frozen soil, as noted by Schimper (65), is physiologically dry; that is, plants cannot obtain water from it. Jost (31), however, states that some plants may obtain water from a frozen soil.

However, transpiration may take place quite rapidly at rather low temperatures, as shown by Wiesner and Pacher (75). Twigs of horse chestnut and oak, for example, lost 0.32 percent and 0.25 percent respectively of their weight in 24 hours at — 3.5° to — 10.5° C., and 0.199 percent and 0.192 percent at — 5.5° C. to — 13.0° C. Beach and Allen (5) found a loss of from 4 to 9 percent of water in apple-tree twigs during a single week in January with a minimum temperature of — 15.0° F. (— 26° C.). They found also in general that the hardiest varieties were most resistant to loss of water.

Bud scales, corky integument, and especially cutinized protective coverings which were once thought to protect the plant by preventing loss of heat are now regarded as means to prevent excessive transpiration. Wiegand (73), for example, measured the temperature of buds with the bud scales removed and before they were removed, but failed to find any marked difference. Chandler (11) found that buds with the scales removed were slightly more resistant to low temperature produced artificially in the laboratory than were the normal buds. Schimper (65) found that desert plants frequently have a

strong resemblance in their structure and habit of growth to those of polar regions. This would be expected if resistance to cold depends on reducing the transpiration to a minimum.

Sachs (56) observed that the foliage of certain plants wilted when exposed to a temperature above the freezing point. He concluded, as did Müller-Thurgau (45), that this wilting was due not directly to the cold but to the inability of the roots to secure moisture from the cold soil.

Hall (25) states that winter injury to such shrubs as rose trees is frequently due to drying winds when the roots are unable to secure water because of the cold soil.

Experiments at the Arizona station appear to show a definite relation between thickness of the epidermis and the amount of reserve or storage material in spineless cacti and their resistance to freezing.

Perhaps the best evidence that physiological drought is a cause of injury to cereals is the well-known xerophytic structure of the most hardy types. Winter rye and Turkey and Kharkof wheat, for example, are characterized by a narrow leaf and a prostrate habit of growth. The soft winter wheats, winter barley, and the common varieties of winter oats, on the other hand, have broad leaves which usually assume a more or less upright position and hence are more exposed to the wind. The Winter Turf variety of oats has a narrow leaf and a prostrate habit of growth very similar to that of Turkey and Kharkof wheat. This variety is the hardiest of the winter oats. It is much less hardy, however, than those varieties of wheat and barley which are characterized by wide leaves and upright growth.

Federoff (16) observed that wheat was injured much less in protected portions of a field than in exposed portions. The injury was attributed to a March wind when the ground was frozen, there having been no injury during the preceding severe winter.

Kolkunov (32) found that those varieties of wheat with the most pronounced xerophytic characters seemed the most hardy.

Sinz (68) concluded as a result of experiments at the University of Goettingen that those varieties of wheat which seemed to be able to prevent rapid transpiration were among those most highly resistant to cold.

Schaffnit (64), on the other hand, as a result of a study of 200 varieties of wheat during three winters, found no relation between morphological characters and resistance to cold. He concluded that structural differences are unimportant from this viewpoint.

In a preliminary study of several varieties of winter wheat, rye, barley, and oats the author and assistants (61) found no differences in cell structure, epidermal covering, or ability to control transpiration that could be correlated with the great differences in cold-resistance known to exist. Recent data, however, indicate a relation between the ratio of root length to leaf area and ability to survive low temperature. The ratio for Turkey wheat, for example, was found to be about 25 percent greater than that for Fultz, a less hardy variety, and about 40 percent greater than for oats and barley.

Schimper (65) observes that "the capacity to withstand intense cold is a specific property of the protoplasm of certain plants and is quite unassisted by protective measures that are external." "Our present power of observation," he says, "does not enable us to recognize in plants any special protective means against cold."

If physiological drought is a common or the only cause of winter injury, then those plants which are most resistant to drought would be expected to be best able to withstand severe cold. This relation holds true for many plants, but certainly it does not for all. Bromegrass, for example, is markedly resistant to both cold and drought but Kentucky bluegrass, timothy, meadow foxtail, reed canary grass, clover, and alsike clover, which are very resistant to cold are adapted to humid areas only. Piper (54) states that red clover is probably more resistant to cold than alfalfa and that alsike clover, which is grown only under humid conditions, is more resistant to cold than either red clover or alfalfa. White clover, which, according to Piper, occurs northward to the limits of agriculture, grows only where moisture is fairly abundant.

Schimper (65) notes that in central Europe delicate plants like *Bellis perennis* and *Stellaria media* are exposed to the weather without any hairy covering or protective layers of any kind, not even a thick cuticle. They are frozen hard and brittle as glass, but when spring comes they continue to grow undisturbed.

In conclusion, the experimental and observational evidence does not permit one to deny or affirm that physiological drought is a cause of injury in all cases. One familiar with winter grains in the Great Plains of the United States can hardly escape the conviction that exposure to cold, dry winds when the ground is bare and frozen is very injurious. On the other hand, in certain northern areas winter wheat is usually killed close to the ground, so that not a spear of green can be seen. In the spring the plants start growth apparently as vigorously as though the green leaves had been retained.

Also, there seems to be little evidence to show that the well-known difference in hardiness of winter oats and barley on the one hand and wheat and rye on the other is due to the greater ability of the latter to control transpiration or to absorb water from a cold soil. Barley and oats are killed much more easily than wheat and rye when covered with snow or protected from transpiration in other ways.

Probably, easily injured plants are killed before physiological drought can have any marked effect. Plants which are able to survive temperatures that freeze the ground as deep as the roots penetrate, however, must frequently be exposed to the effect of physiological drought. Any habit of growth or structure which enables a variety to reduce the transpiration in proportion to the water obtained from the soil or any character or quality which permits it to survive with less water would presumably prolong its life in comparison with those varieties which lack this ability.

### DIRECT EFFECT OF LOW TEMPERATURE.

There can be no doubt that plants are often killed by the direct effect of cold on the tissue without heaving, smothering, or physiological drought taking place. But the final effect of a given temperature is modified and influenced by so many factors both external and internal that the nature and the exact cause of such injury is difficult to determine. In general, it may be attributed to one or more of four groups of factors, viz., (1) mechanical injury, (2) desiccation of the protoplasm, (3) chemical effects, and (4) suspension of metabolism. It is evident that two or more of these results may occur in the same tissue at the same time.

*Mechanical Injury.*—Early observers believed that plants were able to develop heat and so prevent the formation of ice. Early Greek philosophers who were unaware of the cellular structure of plants thought the injury to be due to the rending and mashing of the plant organs by the formation of ice. Du Hamel and Buffon presented the theory in 1737 that death was due to rupturing of the cell walls.

Geoppert (20) found that ice formed both within the cells and in the intercellular spaces. Müller-Thurgau (45) decided as a result of careful study that ice usually formed in the intercellular spaces, and within the cells only in case of rapid freezing or in exceptionally large cells. Müller-Thurgau also proved that in some cases the formation of ice was the cause of death, since certain plants when supercooled were not injured, but were killed if ice formed at the higher temperature.

Wiegand (74) has shown that the formation of ice may separate different tissues. In leaves rich in water the ice fuses into a sheet, completely separating the upper layers from the lower. In twigs the outer layers may be entirely separated from the inner. However, he found in the case of hardy plants that the separation of the cells by the ice masses ordinarily causes no injury.

Gassner and Grimme (18) attribute injury to green plants to volumetric alterations rather than to any peculiar effect on the plant cells.

Others attribute injury to the evaporation of the water frozen in the intercellular spaces before it can be absorbed by the cells. The injury in such cases is regarded as a result of the thawing rather than of freezing and is severe in proportion to the rate of thawing. If the tissue is thawed slowly the water returns to the cells and they regain their turgidity without injury. If they are thawed rapidly, much of the water is evaporated before it can be absorbed. The protection afforded by spraying tomatoes, chrysanthemums, and other tender plants when frozen as often practised by gardeners is probably explained in this way.

There thus appears to be good evidence that death in many plants is a direct result of mechanical injury caused by the ice. In others, especially the more resistant species, ice may form without apparent injury. Schimper (65) notes, for example, that alpine plants "while in blossom pass the nights in a completely frozen state and during the daytime are exposed to the most intense insolation" and states that perennials of the temperate and cold zone "may be frozen into lumps of ice without dying."

*Desiccation.*—According to the most commonly accepted theory, winterkilling is due to desiccation of the protoplasm when the water is withdrawn and frozen in the intercellular spaces. This theory explains the injury much the same as physiological drought, except that in the latter case water permanently leaves the plant tissue, while in the former the protoplasm loses its water, although it is retained in the plant tissue as ice. Physiological drought can cause death only when the soil is very cold or frozen, and theoretically may do so without actual freezing of the plant tissue. Death from desiccation of the protoplasm may occur regardless of the temperature of the soil, but only when the tissue is frozen.

Wiegand (74) remarks that "it seems likely that death from freezing is usually if not always due to drying out of the protoplasm beyond its critical water content. Müller-Thurgau (45) determined the amount of water withdrawn from the cell and frozen in the inter-

cellular spaces and found that 63.7 percent was so withdrawn at — 13° and 79.2 percent at — 15.2° C. Both he and Molisch hold that death is due to the withdrawal of water from the cells.

Adams (2) subjected dry and moist seeds of peas, barley, flax, turnips, red clover, meadow fescue, and timothy to the temperature of liquid air. Germination of the moist seed was greatly reduced, the injury being attributed to withdrawal of water from the cells and freezing in the intercellular spaces.

Schaffnit (64) studied the effect of low temperature on the cell sap, chemical constituents, enzymes, physical changes, and death points of green plants, spores, and pollen grains. He divided them into three groups with respect to their ability to survive low temperature and to withstand desiccation. The first group are those for which water is absolutely essential, the second group can withstand a certain degree of desiccation, and the third can stand complete drying. For the first group the abstraction of water is regarded as the primary cause of death and chemical and physical changes secondary factors. It is claimed that temperatures near the freezing point produce in some plants chemical products which represent a transition from the less stable to the more stable forms. The conclusion is reached that for a given temperature "death results from vital reactions called forth by the external conditions."

*Chemical Effects of Cold.*—The injury to plants from low temperatures have long been regarded as possibly due to chemical changes taking place in the protoplasm. Abbe (1) in his review in 1895 notes that the chemical changes brought about by frost are thought to be of principal importance. He states that Kunnisch likens the chemical change in frozen sap to freezing out of cryolites from ordinary solutions at specific temperatures.

Gorke (21) found that certain proteids are precipitated when plants are frozen and apparently those plants are most easily killed whose proteids are precipitated at the highest temperatures. He found, for example, that in the easily injured begonia a denatured precipitate of proteid is obtained at — 3° C., while in winter rye the proteid is precipitated at not less than — 15° C. and in pine needles at not less that —40° C. Gorke also found that the acidity of sap increases on cooling, which he believed aided in the precipitation and denaturing of the proteids of the cell. He presents the theory that death may be due to this precipitation and to the denaturing effect which prevents the reabsorption of the proteids on thawing. The precipitation of the proteids was believed to be due to the greater concentration of

the cell sap as the water is extracted and frozen in the intercellular spaces, it being well known that certain proteids are precipitated in a concentrated salt solution.

Schaffnit (62) found that proteids of rye grown in the open at low temperatures are not readily precipitated by freezing, while the proteids of rye grown in the greenhouse at a high temperature are readily precipitated. He concluded that the precipitation of the proteids is the only way in which the loss of water from freezing kills plant tissue.

Lidforss (34) found that tender seedlings placed in a sugar solution for a time were able to survive several degrees lower temperature than seedlings not so treated.

Chandler (11) found a decided protective effect from treating seedlings of tomatoes, cabbage, cowpeas, kale, lettuce, and the buds and blossoms of apples, peaches, and cherries with sugar and glycerine solutions. He argues against the theory of Gorke, however, since certain salts which most readily prcipitate proteids did not reduce the hardiness of plant tissue when absorbed by it, and in the case of zinc sulfate seemed to increase the ability to survive low temperatures. Also, he found, no precipitation of proteids in the sap of tender twigs of apple, plum, or pear even in early autumn. Some slight evidence was secured that proteids in sap from greenhouse plants of cabbage, tomato, kale, lettuce, and peas were precipitated by low temperature. Chandler concluded that precipitation of the proteids does not explain death.

Lidforss (34) gives an interesting explanation of the non-precipitation of proteids in resistant plants as a result of investigations concerning the winter green flora of southern Sweden. Of many plants belonging to a variety of ecological types, none appeared to possess any obvious protection against the effects of low temperature. This especially was found true of many delicate herbaceous annuals such as *Holosteum, Cerastium, Lamium, Veronica, Senecio, Viola, Fumaria,* etc. In all, however, the starch which was contained in their tissue changed to sugar on the approach of winter, and again changed to starch on the approach of spring. The sugar by increasing the concentration of the sap reduced the transpiration and the freezing point of the sap, and prevented the precipitation of the proteids.

Maximow (40) conducted extensive experiments to determine (1) if the death point of plants depends on the plant structure alone or if it varies with the physico-chemical condition of the plant; (2) if

there is a diminishing of the death point as a result of introducing various substances into the plant cell, and (3) the relative protective value of different substances. He concluded that (1) the introduction of neutral substances such as alcohols, sugars, and salts may considerably increase the cold resistance of the cells; (2) the protective action of the solution can not be explained alone by the depression of the freezing point, since the resistance to cold always increased more rapidly than this depression; (3) the degree of protection is closely related to the eutectic point of the introduced solution, substances with a high eutectic point showing no protective effect; and (4) isotonic solutions of different substances with low eutectic points possessed nearly the same protective action. Additional experiments showed no relation between the rate of penetration of the protective substance and the degree of protection. From this it was concluded that protection depends on the solution reaching the outer layer only of the protoplasm.

In other experiments Maximow (39) concluded that killing by cold is probably due not simply to low temperature as such (implying a specific minimum temperature) but to physico-chemical changes set up in the plasma colloids during the formation of ice.

*Metabolism at Low Temperature.*—Molisch (42) has shown that plants continuously exposed to a temperature too low for normal metabolism but above freezing will eventually die. Hilliard et al. (28) state that bacteria may be killed by continued low temperature because of its interference with metabolism. Yeast, bacteria, and certain molds, according to Blackman (8), can withstand prolonged exposure to the temperature of liquid hydrogen.

The fact that death may result from continued cold above those temperatures which usually cause death may have a practical application, since weak plants probably will succumb quicker than others.

Green and Ballou (22), for example, in a study of injured and uninjured orchards on Catawba Island and the peninsula of eastern Ottawa county in Ohio following the severe winter of 1903–04, found that where the vitality of the trees had been lowered by any cause, such as low fertility or poor physical condition of the soil, San Jose scale, leaf curl, peach tree borers, etc., the injury from cold was increased.

Chandler (11) found that the sap of peach trees in poor nutritive condition has lower concentration and freezes at a higher temperature than sap from vigorous, healthy trees.

## Conditions Which Modify the Degree of Injury.

A serious difficulty in discovering the cause of winterkilling and in securing varieties and devising methods of culture to prevent it is the presence of numerous secondary effects which cloak or hide the primary causes. Some of these factors are external and some reside within the plant itself. Among the most important external factors are (1) duration and intensity of cold, (2) rate of freezing and thawing, (3) protection by (*a*) snow, (*b*) mulches, (*c*) vegetative cover, and (*d*) uneven surface of the ground, (4) moisture content and kind of soil, and (5) habit of growth of the plants. Of the internal factors the following are worthy of mention: (1) Moisture content of tissue, (2) dormancy, (3) concentration of sap, (4) size of cells, (5) means for controlling transpiration, and (6) age of plants or maturity of the tissue.

### Duration and Intensity of Cold.

A common conception is to think of death resulting when a certain specific minimum temperature is reached, this minimum depending mainly on the kind of plant. This view is held by Mez (41) who says that "each plant has its specific minimum point at which death occurs due to the direct effect of cold." Chandler (11) holds that the work of Müller-Thurgau, Voitlander, Maximow, and his own work at the Missouri station entirely refutes this conclusion.

Pfeffer (55) points out that the intensity of any agency required to produce a fatal effect depends not only on its duration but also on many variable circumstances. Hence, the minimum points can only be approximately and conditionally determined.

Schimper (65) says that "every plant can live only at a temperature lying between two extremes termed respectively the upper and lower zero points. Overstepping of these limits sooner or later, but at the latest within two or three days results in death." He observes that the zero points vary for different species and also for different functions of the same species, and that as far as known at no place on the earth's surface is the temperature so low that no plant can withstand it.

Jost (31) quotes experiments of Brown and Escombe and of Thiselton-Dyer showing that certain seeds and spores are not killed when subjected to —200° C. for five days or to —250° C. for a shorter period.

Wiegand (74), from a review of the literature and his own work, concluded that there seems to be little if any evidence that death is

due to shock or over-stimulation or any other action of cold which might produce the so-called cold rigor.

McFayden (37) exposed photogenic bacteria to a temperature of — 190° C. for 20 hours without impairment of the vitality or functional activities of the organisms. Phosphorescent organisms become nonluminous when subjected to the temperature of liquid air but regained luminosity with unimpaired vigor when thawed. The same results were secured when they were subjected to the temperature of liquid air for seven days, and also when subjected to the temperature of liquid hydrogen.

Wheat kernels previously soaked for 48 hours in water warm enough to promote germination were exposed by Wright (79) to a freezing temperature produced by salt and ice. Lots were removed at intervals of two days, dried, and then sown in well-prepared garden soil. There was an almost constant decrease in germination with length of exposure and increase in the length of time required for the plants to appear above ground. On the average, each two days freezing decreased the germination 3.43 percent.

Schaffnit (63) found that the injury to wheat plants increased with duration and lowering of the temperature.

All investigators appear to agree that for plants that may be killed by cold the injury increases with the degree of cold and its duration.

## RATE OF FREEZING.

Perhaps no phase of injury from cold has been the cause of more contradictory evidence than the relative effects of slow and rapid thawing and freezing.

Winkler (77) reported that leaves of evergreens and twigs of other trees can endure from four to six times as much cold if the change in temperature is gradual than if they are suddenly subjected to cold. Winter twigs cooled rapidly to — 22° C. were killed, but if kept for three days at — 16°, two days at — 18° C., three days at — 20° C., two days at — 22° C., three days at — 25° C., and 12 hours at — 30° to — 32° C. they were not all killed.

Chandler (11) found in an extensive series of studies at the Missouri station that the rate of temperature fall is very important, especially for winter buds. He found for example that apple buds may be frozen rapidly enough with salt and ice so that practically all will be killed at 0° F. (— 18° C.) or slightly above, while they will withstand a temperature of — 20 to — 30° F. (— 29 to — 34.5° C.) if the fall in temperature is gradual. It was found that a rapid fall in

temperature was more injurious if it occurred during the first part of the freezing period than if it occurred later. Chandler found that the hardiness of peach buds in a dormant condition is greatly increased by continuous cold preceding the date when the temperature goes low enough to kill. In his opinion, this capacity to withstand a low temperature appears to be due to the slow fall in temperature rather than to hardiness developed as the result of exposure.

Hilliard et al. (28) found that an abrupt fall in temperature had a greater germicidal effect on bacteria than a gradual fall in temperature.

Pfeffer (55) concluded from a review of the literature that "resistant plants withstand rapid and slow cooling equally well and it is doubtful whether a rapid fall of temperature is more injurious to plants killed by freezing than is gradual cooling.

RATE OF THAWING.

Sachs (56) held that the amount of injury was determined by the rate of thawing. Müller-Thurgau (45) showed that the methods used by Sachs were inaccurate and in a large number of experiments was unable to detect any difference in injury due to rate of thawing except in the fruits of apple and pear.

Molisch (42) secured similar results in a large number of experiments.

Chandler (11) found that a lower temperature was required to kill leaves of lettuce if they were thawed slowly than if thawed rapidly, but in the case of all other tests including unripe pears and apples there was no indication that the rate of thawing had anything to do with the amount of injury.

Haberlandt (24) states that living cells of perennial twigs and other hibernating organs must be protected from violent fluctuations in temperature and especially from the effect of sudden thawing.

Wright (79) exposed barely germinated wheat kernels and wheat plants about three weeks old to a temperature of —17° C. over night. A part were then placed in a room at an average temperature of 21° C. and a part in an outdoors cold chamber to thaw slowly with the first moderation of weather. The germinated kernels kept at room temperature showed no signs of life but perished in a few days. Those which were placed in the cold chamber and allowed to thaw slowly "showed themselves to be in a growing condition after thawing."

In another experiment partly germinated wheat was placed in a

freezing box for periods varying from 2 to 36 days. The average decrease in germination for each 2-day period was 3.43 percent when the seeds were thawed somewhat slowly, and 7.59 percent when thawed rapidly.

Wright also reports some experiments of Tantphous in which partially germinated wheat that was frozen and then thawed slowly germinated 86 percent, while that similarly treated but thawed rapidly germinated only 18 percent.

Garcia and Rigney (17) found in a study of fruit trees in New Mexico that if a temperature of 25° or below occurred one to two hours before sunrise the damage was great but if the minimum temperature occurred near midnight and then gradually rose to the freezing point so that the frozen parts had time to thaw before sunrise the injury was insignificant.

Wiegand (73) studied the effect of alternate thawing and freezing on hardy buds and twigs of several species of shrubs and trees. He says: "thawing seems not to harm these tissues in the least, no matter how frequently or how abruptly it is done. I have often tried the experiment of transporting twigs abruptly from — 18° to the warm laboratory (21° C.) and back several times, thus alternately thawing and freezing them. No matter how many times this was repeated no injury could be detected in the buds even when subsequently placed in the greenhouse to grow.

The conflicting results indicate that some important factors are involved which the experimental methods have not controlled or eliminated. As a working basis it may be suggested that slow freezing may decrease the injury by (1) preventing the formation of the ice within the cells, (2) by giving the tissue an opportunity to dry out, and (3) by permitting the protoplasm to adjust itself to the new conditions. Slow thawing can reduce the injury only on the assumption that death occurs after the tissue begins to thaw. The only theory so far advanced that accounts for winterkilling in this way is by permanent loss of water from the protoplasm. In such cases slow thawing would permit water to be reabsorbed which if thawed rapidly would be evaporated into the air.

Under natural conditions, the drying out of the plant tissue such as occurs in the fall and early winter would appear to be especially important since, as shown later, the moisture content of the tissue is one of the most important factors which determine the injury.

PROTECTION.

Protection of the plants from low temperature and wind during the winter is universally recognized as a most potent factor in preventing winterkilling. Lyon et al. (35) quote figures collected by Boussingault which show a difference in temperature of from 1.5° C. to 8.5° C. due to the snow covering. The writer (57) found a maximum difference of 26° F. (14.5° C.) at a depth of 1 inch in the bottoms of furrows and on the surface, most of the difference being due to the snow.

Bouyoucos (7) compared a bare soil and one covered with vegetation and snow. Observation for four years showed that in exceptionally cold weather the temperature of the protected soil may be 25° F. (14° C.) higher than the bare soil at a depth of 3 inches. He concluded that a cover of vegetation is one of the most efficient and expedient means of protecting the soil from low temperature during the winter. He attributed the effect to (1) arresting cold air currents which come in contact with the bare soil and (2) to air spaces formed by the vegetation, which are poor conductors of heat.

Delwiche and Moore (13) found that a cover crop in an orchard decreased the depth of freezing at least one half.

Carleton (10) claims that tillering bears an important relation to cold resistance because the larger number of culms per unit area permit only a minimum exposure of each to the weather.

On the other hand, in certain rate-of-seeding tests a larger percentage of plants survived with thin than with thick seeding. The writer (60), for example, found in tests conducted for the U. S. Dept. of Agriculture at Newell, S. Dak., that winter wheat sown at rates of 2 and 4 pecks per acre survived with a perfect stand, while 4.3 percent of the plants were killed when the rate of seeding was 6 pecks and 19.4 percent were killed when the rate of seeding was 8 pecks per acre. Again, in experiments at the Kansas station (61) in which wheat was sown in furrows at the rates of 4, 6, 8 and 10 pecks per acre, the winterkilling increased with the rate of seeding. The percentage survival was 75.4 for seeding 10 pecks per acre, 91.0 for 8 pecks, 91.3 for 6 pecks, and 92.8 for 4 pecks per acre. Hume et al. (29) report a fair survival of winter wheat at Eureka, S. Dak., when 2 and 3 pecks per acre were sown, while that sown 4 and 5 pecks per acre was entirely killed.

Oskamp (50) recorded the temperature at a depth of 9 inches of three plots differently treated. The first was cultivated during the summer and sown to rye in the fall for a cover crop. The second

and third were left in sod, the grass being cut and allowed to lie. The third plot was mulched with straw at the rate of about 15 tons per acre. He concluded "that a system of clean cultivation with a winter cover crop is characterized by extreme diurnal fluctuations in temperature; that a straw mulch equalized these fluctuations to a marked extent, as does also a grass crop, though in a less degree."

Wright (79) conducted experiments at Purdue University in which the effect of a 2-inch covering of straw, a layer of straw beneath the surface, and of manure applied as a top dressing or incorporated with the soil before seeding was studied. The straw, whether applied as a surface mulch or beneath the surface, proved decidedly injurious, but the manure applied either as a mulch or mixed with the soil was beneficial. The wheat was sown late and winterkilling was very severe.

Green and Ballou (22) found a marked contrast in the extent of injury to orchard trees on bare and covered soils. The bare soils froze deeper and the injury was much greater than on soil covered with a mulch or other material. In an experiment a plot on which the sod was removed froze to a depth of 18 inches while a plot with a thin sod covering of grass and weeds froze to a depth of about 8 inches only.

Hume et al. (29) found that 3 tons of straw per acre spread on winter wheat as a mulch late in November prevented winter injury, while that not mulched was entirely killed.

Babcock (4) sowed rows of wheat at the Williston, N. Dak., station in standing corn, on bare ground, and in grain stubble. a part of the rows being covered lightly with straw. Whenever the grain was protected in any way by a covering of snow or straw the winterkilling was very slight or none at all. Wherever the rows remained without covering most or all of the plants were killed.

Bouyoucos (7) compared the temperature of a bare soil and one covered with straw. At a depth of 7 inches the former froze December 11 and the latter February 14. At times the temperature of the covered plot was as much as 10° F. warmer than the bare plot.

Hickman (27) compared the effect of a light straw mulch not more than half covering the ground, a medium mulch which covered the ground, and a heavy mulch from 2 to 2½ inches thick. The effect on winterkilling was not recorded, but the heavy and medium mulches reduced the yields considerably. It is stated that the light mulch may have been of some value.

Plumb mulched two wheat plots in January, spreading the straw

about 3 inches deep in the loose condition. Two unmulched plots similarly treated in other respects produced about a bushel more grain than the mulched plots. The effect on winterkilling is not recorded.

Mulching with 2 inches of straw failed to prevent winterkilling of wheat at the Indian Head, Manitoba, Experimental Farm in 1890. The only difference observed was that the mulched portions of the field remained green a few days longer than the others.

Clark (12) reported an average survival of 33 percent for several varieties of winter wheat at the Dickinson, N. Dak., substation, when sown on corn ground with the stalks left standing as compared with a survival of 19 percent when sown on fallow. The average yields were 13.5 bushels for the corn ground and 4.7 bushels for the fallow. The difference was attributed to the standing stalks catching the snow and protecting the plants during the winter.

Hume et al. (29) secured a yield of 28.7 bushels of winter wheat sown on corn ground as compared with 19.2 bushels when sown after oats. Winter rye after corn produced 41.9 bushels per acre as compared with 26 bushels after rye.

In another experiment wheat sown in "narrow troughs with a double disk drill" came through a severe winter in good condition while the wheat on another field harrowed quite level after seeding was entirely killed. Additional data regarding the protection afforded by seeding in furrows is fully discussed by the writer in another paper (56).

Neveroff (48) reported the effect of rolling a field covered with snow and then plowing so as to leave the snow in ridges to catch more snow. He found that the compacted snow melted slower in the spring and so prevented the crop from starting so early and being injured by following cold weather. The highest gain for this treatment in eleven years with winter rye was 1,060 pounds per acre and the least gain 84 pounds per acre. The treatment was also found to increase the yield of oats grown after the rye. In another experiment plowing the snow without rolling increased the yield of clover from 320 to 520 pounds per acre and alfalfa from 315 to 915 pounds per acre.

The author has pointed out in another paper (59) the surprising fact that in North America winter wheat does not appear to be able to survive lower winter temperatures in areas of heavy snowfall than in those where the snowfall is normally light, the difference if any being in favor of the latter locations. Smith (69), in a study

of the relation of meterological factors to the production of winter wheat in Ohio, found on the average no benefit from a snow covering or damage from lack of it. A snowfall in January appeared to be favorable but a snowfall in March was decidedly detrimental. These conclusions are so opposed to common belief that a brief discussion seems called for. As pointed out in the article referred to above the failure of snow to protect is probably in part due to saturating the soil with water in the spring and so causing more damage from heaving. It may also be explained in part by the fact that a wet soil when frozen is often colder than a dry soil, as shown in another part of this paper. A snow early in the winter would also be more effective than later since in the former case it would aid in holding the heat still present in the soil while later in the winter most of the heat would have been lost.

### KIND OF SOIL AND MOISTURE CONTENT.

The kind of soil and its moisture content undoubtedly have an important relation to winter injury. Hunt (30), for example, says that the loamy soils of the corn belt which are usually friable and well supplied with organic matter are not so well adapted to wheat as the clay upland soils, because on the former wheat is likely to winterkill in unfavorable seasons. Montgomery (44) says that all heavy soils in humid regions heave, due to alternate thawing and freezing. Carleton (9) states that the black waxy soil of north central Texas is so stiff and heavy that it cracks and heaves badly in the spring, thereby exposing the wheat roots to the weather. Bouyoucos (7) found that a peat soil thawed 8 to 10 days later in the spring than others, due to the large quantity of water it contained.

Petit, according to Patten (52), found that the passage of frost into the ground is fastest for quartz sand, slower for clay, and slowest for humus (peat). "For continued frost the soil temperature sinks after freezing faster and deeper, the lower the moisture content of the soil, and conversely for thawing of the soil."

The author (57), in experiments conducted at the Kansas station, found that the temperature of wet clay and loam fluctuated less and the daily minimum temperatures were higher than for dry soil of the same kind until both were frozen. After they were frozen, however, the fluctuation in temperature was usually greater and the minimum temperatures lower in the wet soil. The temperature of sand fluctuated more than dry clay or clay loam and as a result was the coldest as measured by the daily minimum temperature. A dry

sand was found to be colder than wet sand whether frozen or unfrozen. The winterkilling of grains sown on these soils followed very closely the average daily minimum temperatures.

### HABIT OF GROWTH OF PLANTS.

The relation of habit of growth to winter hardiness has been discussed, as far as its relation to physiological drought is concerned. But it is quite likely that plants with prostrate leaves are subjected to less extreme temperatures than those which are upright and fully exposed to the air. This especially is true when the ground is covered with a light snow or where there is a heavy vegetative growth. The greater resistance to cold of Turkey and similar types of wheat as compared with soft varieties may be due partly to this fact.

### MOISTURE CONTENT OF TISSUE.

The moisture content of the plant tissue is among the most important of the internal factors which influence winter hardiness. Sinz (68) concluded from experiments conducted at Goettingen that different varieties of wheat show a graduation in the amount of dry matter which is in direct relation to their resistance to low temperature.

Shutt (67) determined the moisture content of twigs of fruit trees at Ottawa, Canada. He concluded that the data gives "direct and definite proof that there is a distinct relationship between the moisture content of the twig and its power to resist the action of frost, and that those trees whose new growth contain the largest percentage of water as winter approaches are in all probability the most tender."

Schaffnit (63) notes that resistance to cold of some varieties of wheat seems to show a relation to the water content, an increase rendering the plant more sensitive to outside influences. Detmer (15) noted that wheat loses its vitality when frozen apparently in proportion to its moisture content.

La Tourette (33) in experiments conducted under the direction of the writer found a direct relation between the moisture content of ungerminated wheat and resistance to low temperature. In nearly all cases the grain containing the most water suffered the greatest injury.

Wiggans (76) soaked seeds of various kinds in water for three hours. Each kind was then divided into three lots, one of which minated immediately, another frozen for twenty-four hours w degrees below 0° C. and germinated, and the third lot

frozen with the second, treated with ether and germinated. The freezing reduced the germination markedly in all cases but the injury was less when followed by etherization. The average germination of the seeds which were soaked but not frozen was 60 percent, of those that were frozen but not etherized 24.6 percent, and of those which were frozen and then treated with ether 28.6 percent.

Chandler (11) found but little difference in moisture content of unfrozen cortex in seasons when it is very tender and in seasons when it is very hardy. De Candolle (14) and Picet (53) subjected dry seeds to a temperature of —80° without injury, while seeds swollen in water were killed at a much higher temperature. Adams (2) found that seeds containing less than 12 percent of water were uninjured when exposed to the temperature of liquid air, but those seeds which were moist when frozen were practically all killed.

Becquerel (6) exposed seeds of castor beans, pine, squash, buckwheat, corn, wheat, oats, beans, lupines, peas, vetches, alfalfa, and radish to the temperature of liquid air (—185 to —192° C.) for 130 hours. It was found that the ability to withstand the low temperature depended on the amount of water and gas present. In the case of moist seeds cold disorganized the protoplasm and nucleus, making germination impossible. But if the protoplasm has reached its maximum concentration by drying and at the same time its minimum activity the low temperature was not injurious.

## DORMANCY.

A condition closely related to moisture content of the tissue and probably not less important in its relation to winterkilling is dormancy.

Chandler (11) found that the most important feature affecting hardiness of fruit trees is maturity of the tissue. He states that in the peach-growing districts of southern Missouri and in Arkansas the most important factor that determines the loss from low temperature is warm periods during the winter which start the buds into growth. It is said that killing of peach buds in Connecticut, New Hampshire, and the peach regions of Canada generally occurs when a cold period follows a thaw.

Selby (66) attributed the injury to orchard trees and shrubbery in Ohio in 1906–7 largely to high rainfall and temperature during the preceding fall, which induced late growth and high moisture content of the tissue. Allen (3) found that those varieties of apple trees which mature their wood early were the most hardy.

Thayer (70), as a result of observations on winterkilling of peach

buds, found that winter hardiness consists in resistance to the effects of warm periods during the winter rather than resistance to low temperatures. It is observed that the relative hardiness of varieties for a winter continuously cold may be extremely different than for a more favorable season.

The effect of sudden freezes following a warm period is not unknown among cereal growers. Georgeson et al. (19) note, for example, that in 1894 the wheat crop at Manhattan, Kans., and elsewhere in the state was almost a failure because of a week of cold weather the latter part of March following a period of unusual mildness. The interesting fact is noted that Turkey wheat survived better than others because it was somewhat later in starting growth.

Nelson (46) attributed the severe injury to winter oats at the Arkansas station in 1910–11 to a sudden drop in temperature following a period of good growing weather.

La Tourette (33) found in experiments previously noted that ungerminated wheat was injured much more by freezing if it had been soaked in warm water than if it had been soaked in cold water previous to freezing. Fleming and the writer (61) froze plants of winter wheat, winter oats, winter rye, and winter emmer at a temperature of —4 to —5° C., the plants having been grown in the greenhouse. Three separate experiments were performed. In general those grains known to be hardy when grown in the field were injured practically the same as the least hardy.

### AGE OF TISSUE.

Chandler (11) found no constant relation between maturity of tissue and resistance to cold. Young leaves of fruit trees were found to kill at a higher temperature than old leaves. He also found no relation between rate of growth and resistance to low temperature, but exposure to low temperature previous to freezing increased the resistance.

Observations on peach buds by Thayer (70) seemed to show that buds on young trees are more apt to be injured than on mature trees. The well known fact that late-sown fall grains are much less likely to survive than those sown at the proper time is probably due mainly to the more tender tissue of the young plants.

### CONCENTRATION OF SAP.

Ohlweiler (51) extracted the sap of a number of trees and shrubs and determined the freezing point. From the data collected and observations on the injury sustained from a late spring frost he

arrived at the following conclusions. (1) That extreme differences in sap density in general are accompanied by a corresponding difference in resistance to freezing. (2) That exceptions to this general rule are probably due to differences in cell structure and other causes such as protective locations, etc. (3) That when the cell structure is the same the densities of the cell sap indicates the relative hardiness. (4) That in plants of the same genus or in varieties of the same species differences in sap density correspond to differences in their resistance to freezing.

Harris and Popenoe (26) state that sap extracted from the West Indian type of *Persea americana* froze at a higher temperature than that of the Mexican and Guatemalan types, and that horticultural experience shows the former to have the least capacity to withstand low temperatures. The authors conclude, however, that the cryoscopic constants of the sap does not always determine the degree of hardiness.

Chandler (11) found from extensive experiments with various plants that increasing the sap density of easily killed tissue by absorption of glycerin, sugars, and mineral salts reduced the injury from freezing.

Wright (79) concluded from experiments with the leaves of wheat that the sap froze much more readily when extracted than when contained in the leaves and that the power to resist freezing is increased by exposure to low temperatures.

Fleming and the writer (61) found that if plants of wheat grown in the greenhouse were frozen when turgid they were killed at a temperature only a few degrees below zero, but if they were allowed to become wilted before freezing they were injured very slightly or not at all. Comparisons of the freezing point of the extracted sap of different kinds of winter grains failed to indicate any significant relation to winter resistance.

## STRUCTURE OF TISSUE.

Wiegand (74) studied the formation of ice in cell tissue under the microscope and determined the size of the cells and the moisture content of the tissue. Of twenty-seven trees examined there were only eight in which no ice was found in the buds at —18° C. In four of the eight, minute ice crystals were found at —26.5° C. A comparison of seven of those in which ice was formed at —18° C., and of seven in which no ice was found at that temperature showed the latter to contain much less water and to have thicker cell walls and slightly smaller cells.

Beach and Allen (5) found a correlation between the density of the wood of apple trees and hardiness, but exceptions were found. The hardier varieties were found to evaporate water less rapidly than the less hardy sorts and hence were better able during cold weather to maintain a balance between absorption and transpiration. This difference was thought, however, more likely to be due to a greater concentration of the sap than to a difference in structure of the wood.

MacFarlane (38) observes that "all thermo-resistant plant structures are said to have a rich and relatively dense protoplasm or a stored mass of reserve material in the cells that contribute to their thermo-resistant qualities. These qualities are aided by the occurrence of mucilaginous walls or cell contents, thick, and pigmented cellulose or cuticularized walls."

## CONCLUSIONS.

Conclusions regarding the causes of winterkilling of cereal crops at this time would be decidedly premature. There can be scarcely any doubt that death occurs as a result of heaving of the soil, smothering, and direct effect of low temperature on the protoplasm. No doubt physiological drought causes injury and differences in resistance of certain cereals may perhaps be explained by their ability to absorb a larger quantity of water from the soil in proportion to the amount transpired.

The duration and intensity of cold, rate of freezing, and in certain cases the rate of thawing and protection afforded by mulches, snow, and uneven surface of the gound are important factors. The moisture content of the tissue and its condition with respect to dormancy often have a determining influence.

The following outline indicates the probable relation of the different factors.

- Causes of winterkilling
  - Heaving
  - Smothering
  - Direct effect of low temperature
    - Desiccation
    - Chemical effect of cold
    - Metabolism at low temperature
  - Physiological drought
- Conditions which modify the degree of injury...
  - Duration and intensity of cold
  - Rate of freezing
  - Rate of thawing
  - Protection
  - Kind of soil and moisture content of soil
  - Habit of growth of plants
  - Moisture content of tissue
  - Dormancy
  - Age of plants
  - Concentration of sap
  - Structure of tissue

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## AN ANNUAL VARIETY OF MELILOTUS ALBA.[1]

H. S. COE.

In the winter of 1916 a quantity of *Melilotus alba* seed which had been grown in Hale County, Ala., the previous summer was purchased for experimental purposes. This, together with seed which had been grown in Mississippi, Kentucky, Kansas, Montana, Wyoming, South Dakota, and North Dakota, was sown in adjacent plats at Redfield,

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication October 22, 1917.

S. Dak., on April 15, 1916, and at Fargo, N. Dak., on May 27, 1916. No nurse crop was used at either place.

At Redfield, approximately 5 percent of the plants on the plat sown with Alabama seed flowered abundantly and matured seed in September, 1916. The remainder of the plants on this plat, as well as all the plants on the other seven plats, made a typical first year's growth for *Melilotus alba*. During the first year typical *Melilotus alba* plants produce an upright, leafy, branching growth but no flowers. The taproot becomes much enlarged at the crown and in late summer or early autumn a varying number of buds form at the crown and serve to produce the first growth the following season. The plants which flowered grew to a height of 3.5 to 4 feet, whereas those which did not bloom made an average growth of 2 to 2.5 feet.

At Fargo, the same as at Redfield, approximately 5 percent of the plants on the plat sown with Alabama seed flowered abundantly. By August 21 the plants on all of the plats had made a 36-inch growth and were cut for hay, leaving an 11-inch stubble. From that time until October 4 the annual plants made a second growth of 18 to 24 inches, whereas the biennial plants made no more than a 6-inch growth. The second crop of the annual plants bloomed profusely but the pods did not mature on account of frost. All plants in the other seven plats made a typical first year's growth for *Melilotus alba*.

A careful examination of the plants which flowered at both stations showed that in most respects their botanical characters were indistinguishable from those of a second year's growth of *Melilotus alba*. The leaves of the plants which flowered the first year under field conditions, as well as the leaves of the plants grown in the greenhouse the following winter from the seed of these plants, were as a whole more oblanceolate and more distinctly serrated than the leaves of the second year's growth of the typical *Melilotus alba* plant. There was no difference in the venation of the seed pods, a character which is used often to distinguish the different species of Melilotus. However, the most striking difference between the plants which flowered the year of seeding and those which did not flower until the summer of 1917 was in the type of root produced. Without a single exception the plants which bloomed the first year at both Redfield and Fargo produced typical annual taproots with no enlargements at the crowns and with no crown buds. None of these plants lived through the winter of 1916–17, whereas only a small percentage of the normal plants of *Melilotus alba* winterkilled.

Seed was collected from a number of the annual plants at Redfield in October, 1916. On January 27, 1917, 275 seeds were sown in in-

dividual pots in the Department's greenhouse. Plants were produced in 255 pots and by May 25 they had made a growth of 4.5 to 5.5 feet and were in bloom. Examination of the roots of these plants showed that they were typical annual taproots and that the root growth compared favorably with that made by the parent plants under field conditions. An attempt has been made at different times to have typical *Melilotus alba* bloom directly from seed in the greenhouse but the only flowers that have been obtained thus far have been produced from branches from crown buds after the plants had been permitted to pass through a resting stage. Under field conditions the only flowers which have been obtained on the first year's growth of *Melilotus alba* were on plants which were started in the greenhouse early in February, 1916, and which were transplanted to the nursery at Arlington Farm in April. Three of these plants out of a total of 100 produced several racemes apiece in October, but they also produced an abundance of crown buds and lived through the winter.

It is very possible that the white-flowered annual variety may be found in more localities of the South than the one mentioned, as several letters and specimens were received the past year from persons who had purchased southern *Melilotus alba* seed and who stated that some of the plants bloomed the year the seed was sown.

It is probable that this plant will be of considerable economic value in the southern portion of the Gulf States as a winter legume and in the central and northern portions of the country as a summer hay crop and for green manure. The acreage of *Melilotus alba* seeded on winter grain or with spring grain to be turned under in the autumn for green manure or cut for hay is rapidly increasing. The most serious objection to this practice is the difficulty of completely eradicating the plant by fall plowing. In addition to making more growth after harvest than spring sowings of the biennial variety, no trouble will be experienced in eradication when the annual variety is used.

In view of these facts it is believed that this plant is worthy of botanical designation. Specimens have been placed in the herbarium of the New York Botanic Garden, the National Herbarium, and the Asa Gray Herbarium. The following is a description of the plant:

*Melilotus alba* Desr. var. *annua* n. var. (Annual White Sweet Clover).—Erect or ascending, branching, glabrous or young branches and leaves slightly pubescent; leaves petioled, leaflets mostly oblanceolate, some narrowly ovate to oblong, serrated, obtuse to truncate; corolla white, 4 to 5 mm. long, the standard longer than the other petals; racemes numerous, slender, 4 to 15 cm. long; pods reticulate, 3 to 4 mm. long; root becoming 15 to 30 inches in length and enlarged very slightly if at all at the crown. Crown buds are not formed.

# AGRONOMIC AFFAIRS.

## MEMBERSHIP CHANGES.

The membership reported in the last number was 653. The deaths of two members have been reported since that time, and two new ones have been added, so that there is no change in the total membership. The names and addresses of the new members, the names of the deceased members, and such changes of address as have been reported to the Secretary follow.

### New Members.

Jacobs, Daniel C., 112 W. Fairmont Ave., State College, Pa.
Lund, Viggo, Farm Crops Dept., Iowa State College, Ames, Iowa.

### Members Deceased.

Loughridge, R. H.
Schulz, Arthur W.

### Changes of Address.

Bailey, C. H., University Farm, St. Paul, Minn.
Derr, H. B., Agricultural Advisor, Fairfax, Va.
Kemp, W. B., Sparks, Md.
Parker, John H., Experiment Station, Manhattan, Kans.
Petry, Edward J., 115 University St., West La Fayette, Ind.
Schoonover, Warren R., c-o A. R. Gawthrop, R. R. 1, Milford, Ind.
Shoesmith, V. M., The Jennings Farms, Bailey, Mich.
Towle, R. S., Northern Great Plains Field Sta., Mandan, N. Dak.
Walster, H. L., 5616 Kenwood Ave., Chicago, Ill.
Whiting, Albert L., 705 Gregory St., Urbana, Ill.
Wiggans, Roy G., Farm Crops Dept., Cornell University, Ithaca, N. Y.
Woods, Albert F., Maryland State College, College Park, Md.

## NOTES AND NEWS.

The item regarding W. A. Albrecht in the October Journal was in error. Mr. Albrecht still retains his position in the soils department of the University of Missouri.

R. H. Loughridge, a charter member of this Society and professor of agricultural chemistry in the University of California from 1891 to 1909, since which time he has been professor emeritus, died at the

home of his brother at Waco, Texas, on July 1. Professor Loughridge was born at Koweta, near Muscogee, in what was then Indian Territory, on October 9, 1843, graduated from the University of Mississippi in 1871, and received the degree of Ph.D. from that institution in 1876. He held various positions in geological and chemical work in the South from 1871 to 1891, when he was called to the University of California by his former teacher and colleague, Prof. E. W. Hilgard. Professor Loughridge's work in California was mostly along the line of soil physics and soil chemistry, particularly studies of the arid and alkali soils of California.

R. A. Gortner, associate professor of agricultural biochemistry in the Minnesota college, has been made professor and chief of the division of agricultural chemistry in the college and station, succeeding R. W. Thatcher.

John H. Parker, for the past several years assistant in the office of cereal investigations, U. S. Department of Agriculture, since November 1 has been assistant in cereal breeding at the Kansas college and station.

Warren R. Schoonover, instructor in soil biology in the University of Illinois, has enlisted in the gas defense service of the sanitary corps, U. S. Army. He will probably be connected with Overseas Repair Section No. 1.

Arthur W. Schulz, scientific assistant in dry-land agriculture at the Northern Great Plains Field Station, Mandan, N. Dak., was killed by a train at his former home in Kansas early in August.

R. W. Thatcher, for the past several years professor of agricultural biochemistry in the Minnesota college and vice-director of the station, has been elected director and dean of the department of agriculture in the same institution, succeeding A. F. Woods. E. M. Freeman, professor of botany and vice-dean, has been elected dean of the college of agriculture.

H. L. Walster, assistant professor of soils in the Wisconsin college and station, is on leave of absence and is pursuing graduate study in the department of botany of the University of Chicago.

H. J. Waters, president of the Kansas State Agriculture College for the past eight years, has accepted the managing editorship of the Kansas City Weekly Star, the weekly agricultural edition of the well-known daily of the same name.

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# THE AGRONOMIST OF THE FUTURE.

W. M. JARDINE.

*(Presidential Address before the American Society of Agronomy, November 12, 1917.)*

It is a privilege which I esteem highly to stand today in the presence of the assembled representatives of two institutions, the Society for the Promotion of Agricultural Science and the American Society of Agronomy. For the American Society of Agronomy, which I have the honor to represent, it is the tenth annual meeting. The little group of earnest men who met in Chicago ten years ago to organize this society doubtless had visions of the increased service which agronomists might render by such a union of forces. I very much doubt, however, whether their imaginations visualized, even as a possibility, the nation plunged into a world war in the short space of one decade or the service we are now called upon to give.

Since that fatal 4th of August, 1914, all agencies, Federal, State, and private, collective and individual, have been called upon to face a great problem. Men must be fed and clothed before they can fight. A continuous stream of foodstuffs must be kept moving from this country and Canada to our allies and the allied armies at a time when not only is the world's available food supply low, but the stores of wheat in Russia, India, and Argentina are inaccessible. Especially heavy, therefore, is the responsibility resting upon American agriculture. Its problem is not merely one of planting greater acreages of food crops, but of increasing the output with a reduced force of workmen. With the outbreak of war in 1914, the period of abundant labor came to an end. Great war contracts were awarded our manufacturers and available labor was rapidly drawn to industrial centers

by the lure of high wages. Canada immediately began sending her ablest bodied men across the ocean—33,000 of them within six weeks after war was declared and between 350,000 and 400,000 men by April, 1917. Canadian authorities were forced into aggressive action to secure men to keep their industries in operation and many men crossed over from the States to fill the ranks of workers in Canada.

Upon our entry into the war, the government had need of the immediate services of every industry, every organization, and every individual, and the response came promptly and loyally from every quarter. Agronomists at once evinced an all-pervading desire to bring to the immediate assistance of the country every ounce of their strength which might be put to practical use. They frequently proved to be the logical men to form "ways and means" committees for devising plans whereby the maximum production could be secured from every man, every horse, every machine, and every acre of ground, quickly, and at the same time jeopardize in no way the permanence of agriculture. Campaigns for increased crop acreages were initiated and carried to successful completion. Seed stocks were inventoried and made available for those in need. Information on every conceivable point relating to agriculture was given to the public through correspondence, public addresses, and the press. This successful participation of agronomists in emergency work is a splendid tribute to their usefulness. It will be continued with increasing vigor.

In our preoccupation in the present great emergency, however, we must not forget the future. During the present crisis and after it has passed there are two fundamental ideals which agronomists must keep before them. The first is to render such service as will warrant the increasing confidence of farmers. The second is to secure so thorough a training as to be able to understand and appreciate the relationship between the fundamental sciences and agronomy, and to make original contributions to the science of agriculture.

While agronomists have demonstrated their grasp of practical affairs in the present crisis, the fact that they have not always been taken into the wholehearted confidence of farmers must be recognized. College men are still regarded as theorists by a great many farmers. It is a mistake to blame this attitude entirely on the farmer. There is no doubt that impractical methods have sometimes been advocated. We have at times dispensed unsound information and every foolish statement has offset ten true ones. The true statements are accepted by farmers as a matter of course, while the faulty one is too often remembered and regarded as an index to the practical intelligence of the college man.

We need not look far for conspicuous examples of such unsound advice and impractical methods. For years we have advocated the improvement of small grains by mass selection. Until less than five years ago there was perhaps no piece of advice so commonly given out. Yet it is doubtful if this method is actually followed by one tenth of 1 percent of the farmers of the United States, simply because it is impractical, if it is not altogether unsound. What folly to advise the farmer who has 500 acres of wheat to harvest, and who is employing from eight to ten men and twice as many horses, to select enough of the best heads to thrash a bushel of grain! This is a process requiring at least a week's time in the very busiest and most critical season of the year. Furthermore, unless he had given the matter special attention, it is altogether likely that he would secure a poorer rather than a better grade of grain, since he would naturally select the largest and best appearing heads, which would result in many instances in a later maturing strain and one inferior both in yield and in quality.

The ear-row test of corn is another example. This method of improvement has been generally advocated, at least until the last few years, but farmers are not using it because it will not stand the test of practical application and will not fit into the system of farming used by farmers. It is a satisfactory system for the man who specializes on corn growing or who grows corn for seed, but not for the ordinary farmer.

Then, there is the soil mulch. We have advocated this practice strongly and it has been widely accepted and adopted by farmers. Now we are not so sure that the soil mulch really conserves moisture by preventing evaporation or that it aids in nitrate formation. Its value may come mainly from the destruction of weeds. If we must admit there is not so much to the soil mulch as we formerly thought, it will tend to shake the farmers' confidence in us, as well as in the mulch.

How does it come that we find ourselves in the position of having made assertions which we are under the necessity of retracting? The answer in the first two cases mentioned—the improvement of small grains by mass selection and the ear-row test of corn—is undoubtedly the lack of a thoroughly practical attitude toward the farmers' problems. The last case, that of the soil mulch, probably arose largely from the lack of that fundamental, scientific training which will not allow a problem to be dropped until the why as well as the how has been discovered. The agronomist is not alone in having given out

faulty information. Chemists, physicists, and other scientific workers have made similar errors, but this does not excuse the agronomist.

In common with other agricultural workers the agronomist holds a somewhat anomalous position. He is more or less of a middleman between the man of pure science and the man on the farm. He must be scientific enough to understand the principles evolved by the pathologist, the biologist, and the chemist, and practical enough to apply these principles to the business of farming.

A practical point of view is largely the result of boyhood training and an endowment of common sense. The colleges may develop a practical attitude but they cannot endow the constitutionally impractical boy with common sense, brilliant though he may be. As the first requisite of a keen cutting edge is hard steel, so the first qualification of the future agronomist is going to be an abundant endowment of common sense. One cannot put a good edge on soft steel and we who are now directing the training of future agronomists should make it our first article of faith to advise a boy to go into teaching or research in agronomy only when he has shown ample evidence of his thorough-going practicality. In the last analysis, of course, practical information is that which is scientifically correct. I submit, however, that only the acid test of actual farm practice can prove any method, any strain of seed, or any mechanical device to be scientifically correct so far as the farm is concerned. I hasten to caution you who are finding in your experimental studies, new and promising varieties of crops, or new and promising methods of soil tillage—such, for example, as that of seeding wheat in furrows as a means of overcoming winterkilling and soil drifting—against preaching their general adoption until their usefulness has been thoroughly demonstrated on the farms by the farmers themselves.

I suggested a moment ago that the reason why we might have to reverse ourselves in the matter of the soil mulch was that we had not followed the matter clear through and determined why the mulch gave certain results. There are other "whys" that are being pressed persistently upon us. Last year we lost approximately 12,000,000 acres of wheat from winterkilling, the fundamental causes of which no one can explain satisfactorily. The effect of soil acidity on plant growth is a problem that awaits solution. We have no generally accepted method of detecting soil acidity or of determining the lime requirement of soils. What is perhaps the most important problem in soil fertility is no nearer solution today than it was seventy-five years ago when Liebig advanced the theory that crop adaptation and ferti-

lizer requirements of the soil could be determined by chemical analysis. While investigators since Liebig's time have corrected many of the errors which he made and have shown the importance of physical texture and the presence in the soil of organic matter in a state of decay, yet with respect to many of the soil problems confronting the farmer, they can only give general directions, concerning the "why" of which they have only vague knowledge.

Turning from the soil to crops again, what do we know about why one strain of corn outyields another? Perhaps we have gone into the matter far enough to say that one strain is more resistant to smut, insects or drought than the other, but this only presses the matter one step further back and we are again met with an insistent "why." Possibly these are but manifestations of differing hereditary constitutions and these characteristics are directly dependent on definite genetic factors discoverable only by precise analysis.

These problems will not be solved by men just out of college, with only a bachelor's degree. The main responsibility of agricultural colleges is, and will continue to be, the training of young men for rural leadership, as farmers and teachers, and for these our present four-year curriculum is admirably adapted. It provides sufficient electives to permit specialization in animal husbandry, or crops and soils, as the young men may choose, and, on the whole, fits young men to succeed in the practice of diversified farming or in general agricultural teaching. It does not, however, fit men to solve fundamental problems.

In the past, leading men in agriculture have not always been well trained. Because of native ability, practical experience, and the fact that the subject was imperfectly developed and had many pressing problems of a very elementary character, these men with limited training have achieved notable results. The problems of the future will be more difficult and the meager training of the past will not suffice. Perhaps two thirds of our present agronomists have no training beyond that indicated by the bachelor's degree. They labor under the handicap of continually being assigned problems for the solution of which they are not adequately prepared.

With a practical attitude towards the farmer's problems and a practical agricultural education as a foundation, the agronomist who is to achieve notable results in the future must undergo a thorough training in the sciences fundamental to agronomic problems. If crops are his particular interest he not only will need to have a solid ground work in the general sciences but also a specialization in plant breeding,

plant physiology, and plant pathology. If his interest turns towards soils he will need, in addition to fundamental knowledge, special training in chemistry, physics, and bacteriology.

The responsibility for advanced training rests not alone upon the young men who are ambitious to become agronomists but upon us who are already in the field. We may well ask, What about the supply of young men who will constitute the agronomists of the future? To what extent will the war reduce the number of young men entering colleges for agricultural training? An inquiry made since the opening of the present school year reveals the fact that the present enrollment in 21 of the leading agricultural colleges of the country is 68 percent of what it was at this time last year. In these 21 institutions 6,823 young men are enrolled for agricultural work as against 10,011 last year at this time. Many young men are at a loss to know whether they should continue their college work or enlist for military service. The organizations represented here today should take an active interest in this situation. As far as practicable, young men should be encouraged to continue scientific training in agriculture in order to be prepared to help solve the problems of the great period of reconstruction which must follow the end of the war. The American Society of Agronomy must encourage its own members to pursue advanced study. To this end, it should encourage the policy on the part of educational institutions of permitting members of the teaching and research staff to spend time in study at other colleges and universities on part salary. The time has come when the institution that does not extend this privilege to its members and stimulate their acceptance of the privilege will find itself in a state of retrogression.

Never before has the opportunity for service been greater for agronomists. The opportunity to do constructive work in one of the most critical periods in the history of human progress is one to be considered gravely and with renewed courage and determination. The world's difficulties will not all pass with the ending of the war. The making of "two blades of grass to grow where but one grew before" must be accomplished if a hungry world is to be fed at a cost small enough to allow a safe margin for the attainment of happiness. This is the agronomist's problem. It is the agronomist's opportunity.

# AGRONOMIC AFFAIRS.

## REPORT OF THE SECRETARY FOR 1917.

This meeting marks the tenth anniversary of the founding of the American Society of Agronomy. While the actual organization was not effected until December 31, 1907, the plans were under discussion for several weeks previous and officially we are now closing our tenth year. Though conditions through the greater part of the year have been unusual and trying, the Society has continued to increase in membership, while the interest in the JOURNAL has been greater than ever. The war has had its effects on the Society as on everything else, in keeping down the number of new members and perhaps in the loss of a few old ones, though most of the losses will not be recorded until after the beginning of the next year. High prices have also entered into our affairs, preventing in part the increase in the size of the JOURNAL.

The increased membership and the greater frequency of issue of the JOURNAL, together with the greater number of papers handled, has again increased the work of the Secretary and Editor. That official again recommends the separation of the two offices, a recommendation which he will make in detail to the Executive Committee, as that body has the power to choose the editor. As in previous years, the Secretary wishes to acknowledge the hearty cooperation of the Executive Committee and of the Treasurer in particular, and to express his thanks to Misses Jane B. Taylor and Elizabeth C. Lambert for efficient service rendered. He also wishes to take this occasion to express his gratitude to the entire membership for the support they have given him through the three years of his incumbency, the demands of which he feels he can no longer meet with fairness to himself and to the Society.

### I. FUNDS COLLECTED BY THE SECRETARY.

The following is a classified list of funds which have been received by the Secretary, chiefly from dues of new members and from the sale of *Proceedings* and JOURNAL. All these have been transmitted to the Treasurer and have been included in his annual report.

CLASSIFIED RECEIPTS AND DISBURSEMENTS, OCTOBER 28, 1916–OCTOBER 31, 1917.

*Receipts.*

| | | | |
|---|---|---|---|
| To dues collected (itemized list appended): | | | |
| 3 new members for 1916................ | at $2.00 | $ 6.00 | |
| 106 new members for 1917................ | at 2.00 | 212.00 | |
| 4 new members for 1917................ | at 1.50[a] | 6.00 | |
| 3 local members for 1916................ | at .50 | 1.50 | |
| 24 local members for 1917................ | at .50 | 12.00 | $237.50 |

[a] Members of local sections who had previously paid dues of 50 cents each as local members.

| | | | |
|---|---|---|---|
| To *Proceedings* and JOURNAL sold: | | | |
| 14 copies of Volume 1 | at $1.00 | $ 14.00 | |
| 3 copies of Volume 1 | at 1.80[b] | 5.40 | |
| 4 copies of Volume 1 | at 2.00 | 8.00 | |
| 13 copies of Volume 2 | at 1.00 | 13.00 | |
| 2 copies of Volume 2 | at 1.80[b] | 3.60 | |
| 4 copies of Volume 2 | at 2.00 | 8.00 | |
| 14 copies of Volume 3 | at 1.00 | 14.00 | |
| 3 copies of Volume 3 | at 1.80[b] | 5.40 | |
| 4 copies of Volume 3 | at 2.00 | 8.00 | |
| 13 copies of Volume 4 | at 1.00 | 13.00 | |
| 3 copies of Volume 4 | at 1.80[b] | 5.40 | |
| 4 copies of Volume 4 | at 2.00 | 8.00 | |
| 11 copies of Volume 5 | at 1.00 | 11.00 | |
| 4 copies of Volume 5 | at 1.80[b] | 7.20 | |
| 8 copies of Volume 5 | at 2.00 | 16.00 | |
| 11 copies of Volume 6 | at 1.00 | 11.00 | |
| 4 copies of Volume 6 | at 1.80[b] | 7.20 | |
| 8 copies of Volume 6 | at 2.00 | 16.00 | |
| 10 copies of Volume 7 | at 1.00 | 10.00 | |
| 3 copies of Volume 7 | at 1.80[b] | 5.40 | |
| 9 copies of Volume 7 | at 2.00 | 18.00 | |
| 9 copies of Volume 8 | at 1.00 | 9.00 | |
| 4 copies of Volume 8 | at 1.80[b] | 7.20 | |
| 8 copies of Volume 8 | at 2.00 | 16.00 | |
| 44 copies of Volume 9 | at 1.25[c] | 55.00 | |
| 10 copies of Volume 9 | at 1.70[d] | 17.00 | |
| 21 copies of Volume 9 | at 1.80[b] | 37.80 | |
| 56 copies of Volume 9 | at 2.00 | 112.00 | |
| 1 copy of Volume 10 | at 1.80[b] | 1.80 | |
| 3 copies of Volume 10 | at 2.00 | 6.00 | |
| 13 single numbers of Volume 5 to 9 | | 4.40 | $473.80 |
| To extra reprints sold: | | | |
| From January–February, 1916, number | | 5.70 | |
| From March–April, 1916, number | | 13.53 | |
| From May–June, 1916, number | | 4.41 | |
| From July–August, 1916, number | | 1.78 | |
| From September–October, 1916, number | | 2.53 | |
| From November–December, 1916, number | | 1.93 | |
| From January, 1917, number | | 1.18 | |
| From February, 1917, number | | 1.00 | |
| From March, 1917, number | | 3.02 | |
| From April, 1917, number | | 17.80 | |
| From May, 1917, number | | 12.11 | |
| From October, 1917, number | | 2.10 | $ 67.09 |
| To sales of copper and zinc from old engravings | | | 1.98 |
| | | | $780.37 |

[b] Sold through agents at 10 percent discount.

[c] Sold to senior students in agronomy in accordance with decision of Executive Committee.

[d] Sold through foreign agents at 15 percent discount.

*Disbursements.*

| | | | |
|---|---|---|---|
| Jan. 2, 1917, | by check to Treasurer Roberts........... | $159.31 | |
| Feb. 28, 1917, | by check to Treasurer Roberts........... | 307.76 | |
| May 10, 1917, | by check to Treasurer Roberts........... | 110.60 | |
| June 30, 1917, | by check to Treasurer Roberts........... | 72.36 | |
| Oct. 31, 1917, | by check to Treasurer Roberts........... | 130.34 | $780.37 |
| | Balance on hand November 1, 1917 ............... | | $000.00 |

## 2. MEETINGS.

Only one meeting of the Society has been held this year, the present annual meeting. There have been 22 papers presented, 19 in separate sessions of this Society and 3 in a joint session with the Society for the Promotion of Agricultural Science. That the Society is fully alive to present-day problems and particularly problems which have to do with the food supply is shown by the unusual preponderance of papers having to do with some phase of wheat production. The average attendance at the sessions of this Society has been about 90, while the attendance at the joint session was about 225.

## 3. LOCAL SECTIONS.

The Society now has 11 local sections, 2 new ones having been formed during the year, one at the University of Illinois and one at the North Carolina A. and M. College. The local sections of the Society are now located at Cornell University, Georgia State College, the University of Illinois, Iowa State College, Kansas State Agricultural College, Minnesota College of Agriculture, North Carolina A. and M. College, Ohio State University, South Dakota State College, in New England, and in Washington, D. C. These local sections report memberships ranging from 10 to about 65. Most of them hold several meetings a year, at which problems of local agronomic interest are discussed. The membership at several other institutions is sufficient for the formation of local sections, and it is hoped that the coming year will witness still further growth along this line.

## 4. MEMBERSHIP.

The increase in membership of the Society was not so great as in 1916, the banner year, but is greater than in any other year. The number of new members added was 118, 29 less than in 1916, but 11 more than in 1915 and 47 more than in any year previous to 1915. The total number of members added since 1908, when the Society had a membership of 121, is 707, making a gross membership of 828. Of this number, 6 have died, 49 have resigned, and 121 have allowed their membership to lapse, a net loss of 176 and a present membership of 652. The unusually heavy loss by resignation during the year, 24 members, was due to a combination of causes, but perhaps more than anything else to the shifting of men into emergency agricultural demonstration or military work.

In this connection, it is suggested that the Society make some provision for carrying those of its members engaged in military service on its rolls during the period of the war without cost to them. If these men return to agronomic work they should be allowed to renew their memberships without payment of arrearages and, if they desire, to purchase volumes published during their absence at the usual reduced price to members.

No special campaign for members was made during the year, other than the sending out of sample copies and circular letters. The increase in membership is due to these, to the efforts of the individual members, and to the further growth of the local sections. A few members have been particularly diligent in adding to our rolls, and grateful acknowledgment is here made to them. In almost every agricultural college and experiment station in the United States and in Canada men are engaged in agronomic work who are not members of this Society, not to mention hundreds in private work. The membership of the Society should soon reach the thousand mark, but it will not reach that mark soon unless the individual members make special efforts to that end.

## Changed Addresses.

Of the 108 changes of address recorded in the Journal during 1917, 83 were due to change of position. This number is 13 percent of the total membership, as against 11 percent of similar changes in each of the two years previous, showing rather more than the usual activity among agronomists.

## New Members.

The total membership at the end of 1916 was 586. During 1917, 118 new members have joined the Society and 2 previously lapsed have been reinstated. During the same period 3 have died, 40 have lapsed (of whom 13 were later reinstated), and 24 have resigned. The total loss during the year is 54 and the net gain 66, making a total membership of 652. A list of new members for 1917 follows. The addresses of all new members will be found in the various issues of the Journal during the year. Those marked with an asterisk are reported for the first time in this issue.

### *New Members in 1917.*

Agee, John H.
Albert, A. R.
Anderson, A. C.
Andrews, Myron E.
Baker, O. E.
Bell, N. Eric
Binford, E. E.
Booth, V. J.
Brandon, Joseph F.
Brewer, Herbert C.
Briggs, Glen
Brockson, W. I.
Bryant, Roy
Bugby, M. O.
Clark, Geo. H.
Clemmer, H. J.
Cocke, R. P.
Coe, H. S.
Conrey, G. W.
Cramer, W. F.
Criswell, Judson H.
Curtis, Harry P.
Daane, Adrian
Darst, W. H.
Davisson, Bert S.
Deeter, E. B.
de Werff, H. A.
Dickson, R. E.
Dougall, Robert
Douglas, J. P.
Downs, E. E.
Finnell, H. Howard
Fletcher, C. C.
Fletcher, O. S.
Fleming, Frank L.
Foersterling, H.
Frank, W. L.
Freeman, Ray
Furry, R. L.
Graham, E. E.
Gray, Samuel D.
Gray, W. F.
Halverson, W. V.
Hanson, Lewis P.
Harlan, Harry V.
Haskell, E. S.
Hill, C. Edwin
Hill, Pope R.
Hodgson, E. R.
Hodson, Edgar A.
Hoke, Roy
Holland, B. B.
Hotchkiss, W. S.
Huelskemper, E. H.
Hulbert, Harold W.
Hurst, J. B.
Huston, H. A.
Jackson, J. W.
Jackson, L. D.
Jarrell, J. F.
Jarvis, Orin W.
Joslyn, H. L.
Kelly, E. O. G.
Kemp, Arnold R.
Kennedy, P. B.
Kenworthy, Chester
Killough, D. T.
Kime, P. H.
Kraft, J. H.
Kuska, J. B.
*Jacobs, Daniel C.
Langenbeck, Karl
Letteer, C. R.
Lippitt, W. D.
Longman, O. S.
*Lund, Viggo
McIlvaine, T. C.
McNess, Geo. T.

Mathews, Oscar R.
Metzger, J. E.
Miller, Frank R.
Milton, R. H.
Morison, A. T.
Mortimer, Geo. B.
Moynan, John C.
Mundell, J. E.
Murphy, Henry
Murray, James
Nevin, L. B.
Northrop, Robert S.
Osenbrug, Albert
Park, J. B.
Pate, W. F.
Pittman, D. W.
Purington, James A.
Ratliffe, Geo. T.
Reed, Everett P.
Riley, J. A.
Robertson, R. B.
Schuer, Henry W.
Shinn, E. H.
Smith, J. B.
Smith, Howard C.
Southworth, W.
Spencer, E. L.
Taggart, J. G.
Tillman, B. W.
Torgerson, E. F.
Trout, C. E.
True, Rodney H.
Van Evera, R.
Van Nuis, C. S.
Ward, Wylie R.
Ware, J. O.
Wilkins, F. S.
Willard, C. J.
Winters, N. E.
Woo, Moi Lee

### Distribution of Membership.

Of the 652 members of the Society, 609 are in the continental United States, 6 in our island dependencies, 25 in Canada, and 12 in other countries. Of the 6 in our dependencies, 2 are in Porto Rico, 3 in Hawaii, and 1 in Guam. The 25 in Canada represent 7 Provinces, 2 in Alberta, 2 in British Columbia, 5 in Manitoba, 1 in Nova Scotia, 7 in Ontario, 1 in Prince Edward Island, and 7 in Quebec. Of the 12 in other countries, 2 are in Cuba, 1 each in Costa Rica, Brazil, and Paraguay, 2 in South Africa, 2 in China, 2 in India, and 1 in Japan.

We have at least 2 members in every state in the Union, and 5 or more in 31 of the 48 states. The leading state in membership is Illinois, with 36. Kansas ranks second, with 33; then follow Texas, 31; Ohio, 29; New York, 28; California, 22; Iowa, 21; and Indiana, 20. Of the states with less than 20 and more than 10 members, North Dakota has 19; Georgia, Oklahoma, and Wisconsin, 18 each; Minnesota and South Dakota, 15 each; Maryland, 13; North Carolina, 12; and Oregon, 11. Colorado, Missouri, and Washington have 10 each. In the District of Columbia, where naturally a large part of the membership is centered, there are 82 members, excluding and crediting to the states a large part of the men who are on field station duty the greater part of the year.

### Address List of Members.

The address list of members this year, if printed, would occupy 13 pages in the Journal. For the sake of economy, it seems best to omit this list. Changes of address are printed as rapidly as they come to the notice of the Secretary, and the names of new members are printed in each issue. These, in connection with the address list in the last number of Volume 8, make a correct list of the membership.

## 5. JOURNAL AND PROCEEDINGS.

With the beginning of the year, the Journal was changed from a bi-monthly to a 9-number basis, the numbers appearing monthly except during June, July, and August. While there has been some irregularity in the appearance of the monthly issues and some few regrettable errors have been made because of unusual and difficult working conditions, on the whole the Secretary and Editor believes that the Journal has been more satisfactory this year than last. The monthly issuance makes more prompt publication possible, particularly of short

articles for which quick publicity is desired. The total number of pages printed during the year is 432, an 8-percent increase over last year and a 35-percent increase over the volume for 1915. Including those in the December number, 40 papers have been printed, with 9 plates and 23 text figures. These papers have been contributed by 40 authors, who represent 13 states and the District of Columbia.

The increasing cost of publication, particularly the present high price of paper, will make necessary an increase in the income of the Society, if the JOURNAL is to be maintained on the present basis or is to make any progress whatever. While the Secretary regrets very much to make the announcement, the only way to obtain this additional income which seems available is to increase the annual dues. It will be necessary also to conduct a vigorous campaign for new members, for our losses are likely to be far heavier than usual and we must have new men to fill the gaps and to increase our total.

## DISPOSAL OF PUBLICATIONS.

In Table 1 will be found full data on the disposal of *Proceedings* and JOURNAL in the period from October 28, 1916, to October 31, 1917.

The sale of the publications of previous years has been heavier than usual, both the sale of the earlier volumes to those members who desired to complete their sets and the sale of complete or partial sets to libraries. The number of copies of the current volume distributed to libraries shows a further healthy growth, being 88 as compared with 77, an increase of 14 percent. The total income from the sale of volumes earlier than the present one was $239.80, as compared with $133.10 in the corresponding period last year for one less volume.

TABLE 1.—*Data showing the original edition of each volume of the Proceedings and Journal, the distribution made previous to and during 1917, and the number of copies remaining in stock.*

| Edition printed, disposition of copies, and number remaining. | Volumes. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Edition printed | 501 | 517 | 516 | 514 | 750 | 750 | 750 | 750 | 1,050 |
| Previously accounted for | 364 | 373 | 402 | 411 | 638 | 515 | 575 | 668 | ...... |
| Distributed to members, 1917 | .... | .... | .... | .... | .... | .... | .... | ...... | 652 |
| Distributed to subscribers, 1917 | .... | .... | .... | .... | .... | .... | .... | ...... | 131 |
| Sample copies | .... | .... | .... | .... | .... | 37 | 12 | ...... | 16 |
| Lost copies replaced | .... | .... | .... | .... | .... | .... | .... | 13 | |
| Sold, 1917 | 21 | 19 | 21 | 20 | 23 | 23 | 23 | 22 | |
| Total copies distributed | 385 | 392 | 423 | 431 | 661 | 575 | 610 | 703 | 799 |
| Difference | 116 | 125 | 93 | 83 | 89 | 175 | 140 | 47 | 251 |
| Sold on credit orders | 1 | 1 | 1 | 1 | 2 | 2 | ..... | 1 | 1 |
| Copies in stock | 115 | 124 | 92 | 82 | 87 | 173 | 140 | 46 | 250 |

## 6. MINUTES OF THE ANNUAL MEETING.

WASHINGTON, D. C., NOVEMBER 12–13, 1917.

*First Session, Monday Afternoon, November 12.*

The meeting was called to order in the New Ebbitt Hotel at 2 p.m. by President Jardine and the presentation of papers on the regular program was taken up, as follows:

1. Mineral Food Requirements of the Wheat Plant at Different Stages in Its Development (illustrated), by Prof. A. G. McCall.
2. Effect of Sodium Nitrate Applied at Different Stages on the Yield, Composition, and Quality of Wheat, by Drs. J. Davidson and J. A. Le Clerc (presented by Dr. Davidson).
3. Some Facts Regarding the Soft or Flour Corns (illustrated), by Mr. H. Howard Biggar.
4. Drainage Tanks for Soil Investigations—Some Preliminary Studies, by Prof. C. A. Mooers.
5. Organizing Crop Production on the Basis of the Distribution of the Natural Vegetation (illustrated), by Prof. Adolph E. Waller.

The reading of the papers being concluded, President Jardine announced two special committees, as follows:

NOMINATING COMMITTEE.

Alfred Atkinson, *chairman*; F. D. Farrell, and R. W. Thatcher.

AUDITING COMMITTEE.

A. H. Leidigh, *chairman*, and C. A. Mooers.

After announcements by the Secretary regarding the evening session, the sessions of the following day, and several other matters of interest, the session adjourned.

*Second Session, Monday Evening, November 12.*

This session was held jointly with the Society for the Promotion of Agricultural Science for the presentation of the presidential addresses of the two organizations and an address by Dr. Liberty Hyde Bailey, recently returned from extended travel in China. It was called to order by Prof. C. E. Thorne, presiding, with about 225 persons present. The following papers were presented:

The Outlook in Agricultural Science, by Prof. Herbert Osborn, President of the Society for the Promotion of Agricultural Science.

The Agronomist of the Future, by Dean W. M. Jardine, President of the American Society of Agronomy.

Permanent Agriculture and Democracy (as suggested by the situation in China), by Doctor L. H. Bailey.

After the presentation of these addresses, the session adjourned.

*Third Session, Tuesday Morning, November 13.*

This session was called to order by President Jardine at 9 a.m. In accordance with the decision of the previous annual meeting, it was devoted to a discussion of varietal classification and nomenclature. The following papers were presented:

6. The Classification of Western Wheat Varieties, by Messrs. Carleton R. Ball and J. Allen Clark (presented by Mr. Ball).

7. Naming American Wheat Varieties, by Messrs. Carleton R. Ball and J. Allen Clark (presented by Mr. Ball).

8. Classifying Oat Varieties, by Mr. George Stewart (read by Prof. E. G. Montgomery in the absence of the author).

9. Identification of Varieties of Oats in New York, by Prof. E. G. Montgomery.

Professor Montgomery, the chairman of the Society's Committee on Varietal Nomenclature, then discussed the general subject briefly, following which Professor Wm. Stuart, Secretary of the Potato Association of America, pledged the support of that organization in any movement looking toward the standardization of the nomenclature of crop plant varieties. After some further discussion, the Society went into business session.

*(Business Session.)*

On motion, the minutes of the last annual meeting as printed in the JOURNAL (8: 382–385) for November–December, 1916, were approved.

The report of the Secretary was read and, on motion, approved.

The report of the Treasurer was read and, on motion, approved.

The report of the Auditing Committee was read by the chairman, Mr. Leidigh, and was approved, on motion.

The report of the Executive Committee was read by the Secretary and, on motion, approved.

No report was made by the Committee on Soil Classification and Mapping.

The report of the Committee on Standardization of Field Experiments was presented by the chairman, Dr. T. L. Lyon, and, on motion, approved.

No report was made by the Committee on Agronomic Terminology, but a brief statement regarding the work of the committee was made by Mr. C. R. Ball, a member.

The report of the Committee on Varietal Nomenclature was read by the chairman, Prof. Montgomery, and, on motion, approved.

The Society then, on motion, adopted the following resolution proposed by Chairman Montgomery:

*That the American Society of Agronomy appoint a Committee which shall act in cooperation with the American seed trade and any other agencies to secure uniformity in rules and practices of varietal nomenclature and registration.*

The code of nomenclature proposed by the committee was read and, on motion, adopted.

Brief reports of the local sections in Iowa and Kansas were made by Profs. Stevenson and Call, respectively, and reports from the local sections at Cornell University, South Dakota State College, and in New England were read by the Secretary.

The report of the Committee on Nominations was then read by the Secretary, as follows:

*President*, Dr. T. Lyttleton Lyon, Cornell University.
*First Vice-President*, Prof. A. G. McCall, Maryland State College.
*Second Vice-President*, Dr. C. B. Lipman, University of California.
*Secretary*, Mr. P. V. Cardon, U. S. Dept. of Agriculture.
*Treasurer*, Prof. George Roberts, Kentucky Agr. Expt. Station.

It was moved and seconded that the report of the committee be adopted and that the Secretary be instructed to cast the unanimous ballot of the Society for the nominees. Treasurer Roberts then made a brief statement recalling his five years of service and asking that he be relieved from further duty. He pointed out the advantages of having the Secretary and Treasurer located in the same city and urged that the two offices be merged. This suggestion was approved by the Secretary, who stated that the decision regarding the desirability of merging the two offices had been arrived at independently by the present incumbents. The committee's report was then amended by substituting the name of Mr. Cardon for that of Prof. Roberts for Treasurer, the amended report adopted, the ballot cast by the Secretary, and the nominess declared elected.

The Secretary then made a brief statement of the financial condition of the Society, with the estimated income for 1918 and the probable expenditures based on the publication of a volume of the JOURNAL of the same size as that printed in 1917. This statement showed that a deficit was almost certain to result unless the membership dues were increased. It was then moved and seconded that that portion of by-law 1 which reads "The annual dues for each active and associate member shall be $2.00" be amended by substituting "$2.50" for "$2.00." After a short discussion, the by-law as amended was adopted.

On motion, the annual dues of those members who enter the military service were suspended for the period of that service.

On motion, the Society expressed its thanks to the management of the New Ebbitt Hotel for courtesies extended during its sessions.

On motion, the Society expressed its appreciation of the services rendered by the retiring Secretary and Treasurer during their respective terms of office.

The Society then adjourned to meet at 2 p.m.

*Fourth Session, Tuesday Afternoon, November 13.*

The session was called to order by Mr. C. R. Ball at 2 p.m., the President and both Vice-Presidents being unavoidably absent. The presentation of papers was resumed, as follows:

10. Relation of Weed Growth to Nitric Nitrogen Accumulation in the Soil (illustrated), by Profs. L. E. Call and M. C. Sewell (presented by Prof. Call).

11. Wheat Breeding Ideals, by Prof. Harry Snyder.

12. Calcium in Its Relation to Plant Nutrition (illustrated), by Dr. R. H. True.

13. Red Rock Wheat and Rosen Rye (illustrated), by Prof. Frank A. Spragg.

14. The Triangle System for Fertilizer Experiments (illustrated), by Drs. Oswald Schreiner and J. J. Skinner (presented by Dr. Schreiner).

After an announcement regarding the evening session, the session adjourned.

*Fifth Session, Tuesday Evening, November 13.*

The session was called to order at 8 p.m. by Vice-President Lipman and the following papers presented:

15. Some Tests of an "All-Crops" Soil Inoculum by Mr. Paul Emerson.
16. Corn and Wheat Soils of the United States, by Prof. C. F. Marbut.
17. Methods Used in Cereal Investigations at the Cornell Station (illustrated), by Dr. H. H. Love and Mr. W. T. Craig (presented by Dr. Love).
18. The Significance of the Sulfur in Sulfate of Ammonia Applied to Certain Soils, by Dr. C. B. Lipman.
19. Aluminum as a Factor Influencing the Effect of Acid Soils on Different Crops, by Dr. B. L. Hartwell and Mr. F. R. Pember (presented by Dr. Hartwell).

The presentation of papers being concluded, the Society adjourned *sine die.*

## REPORT OF THE TREASURER.

FROM NOVEMBER 13, 1916, TO NOVEMBER 12, 1917.

*Receipts.*

| | | |
|---|---|---|
| Balance on hand, November 13, 1916 | | $ 458.18 |
| From C. W. Warburton, Secretary, per his statements Nos. 1–5 | | 780.37 |
| Membership fees received: | | |
| For 1912, 1914, 1915 (reinstatements) | $ 6.00 | |
| For 1916 | 188.00 | |
| For 1917 | 964.00 | |
| For 1918 | 10.00 | |
| Local memberships, 1917 | 2.00 | |
| Fee for collecting check | .10 | 1,170.10 |
| For JOURNAL, Volumes 7 and 8 | | 2.00 |
| Total receipts | | $2,410.65 |

*Disbursements.*

| | | | Voucher No. | | |
|---|---|---|---|---|---|
| 1916. | | | | | |
| Dec. | 4. | E. B. Thompson, rent of stereopticon | 107 | | $ 15.00 |
| Dec. | 4. | New Era Ptg. Co., printing JOURNAL, $8^5$ | 108 | $192.55 | |
| 1917. | | | | | |
| May | 23. | do. $8^6$–$9^{1-2}$ | 121 | 549.39 | |
| July | 16. | do. $9^3$ | 126 | 174.98 | |
| July | 16. | do. reprints | 127 | 73.53 | |
| Aug. | 29. | do. $9^{4-5}$ | 128 | 430.90 | 1,421.35 |
| 1916. | | | | | |
| Dec. | 27. | L. M. Thayer, printing | 109 | 22.75 | |
| 1917. | | | | | |
| Jan. | 13. | do. | 111 | 19.35 | |
| Feb. | 16. | do. | 117 | 7.75 | |
| May | 23. | do. | 123 | 2.25 | |
| Oct. | 3. | do. | 129 | 13.00 | 65.10 |
| Jan. | 2. | Maurice Joyce Engraving Co., cuts | 110 | 12.74 | |
| Feb. | 5. | do. | 114 | 3.68 | |

| | | | | | |
|---|---|---|---|---|---|
| March 28. | do. ....... | 119 | 9.15 | |
| May 1. | do. ....... | 120 | 33.04 | |
| Oct. 15. | do. ....... | 130 | 12.93 | 71.54 |
| Jan. 13. | C. W. Warburton, Secretary's expenses ... | 112 | 48.90 | |
| March 12. | do. ... | 118 | 22.20 | |
| May 23. | do. ... | 122 | 21.70 | |
| July 9. | do. ... | 125 | 17.35 | |
| Nov. 3. | do. ... | 131 | 43.25 | 153.40 |
| Jan. 13. | M. Kaufman, stamps .................... | 113 | | 15.00 |
| Feb. 5. | Jas. M. Byrnes, printing ................. | 115 | | 4.00 |
| Feb. 5. | Jessie Caswall, clerical help .............. | 116 | | 6.19 |
| June 4. | Ala. Polytechnic Inst., refund ........... | 124 | | 2.00 |
| | Collection fees on foreign checks ........ | | | .85 |
| | Total disbursements ................... | | | 1,754.43 |
| | Balance November 12, 1917 ........... | | | 656.22 |
| | | | | $2,410.65 |

GEO. ROBERTS,
*Treasurer.*

AUDITING COMMITTEE'S STATEMENT.

The undersigned have examined the accounts kept by Prof. Geo. Roberts, Treasurer of the American Society of Agronomy, and consider them in first-class condition. We find the statement of the Society's finances as set forth in Prof. Roberts' annual report correct.

A. H. LEIDIGH,
C. A. MOOERS,
*Auditing Committee.*

## REPORTS OF COMMITTEES.

The reports of two special committees, those on audit of accounts and on nominations, are found elsewhere. The Auditing Committee's report immediately follows the report of the Treasurer, while that of the Committee on Nominations appears at the proper place in the minutes of the business session.

The reports of two of the four standing committees of the Society follow the report of the Executive Committee. The other two committees, those on soil classification and mapping and on agronomic terminology, made no report.

## REPORT OF THE EXECUTIVE COMMITTEE.

A meeting of the Executive Committee was called at Washington, D. C., November 16, 1917, by President Jardine, with all members present.

On motion, it was decided that the next annual meeting of the Society should be held at the same place and on the two days preceding the meeting of the American Association of Agricultural Colleges and Experiment Stations. The matter of holding a sectional meeting with the Great Plains Cooperative Association or the Dry Farming Congress was referred to the President and Secretary, with power to act.

On motion, the Secretary was instructed to continue as Editor of the JOURNAL during the ensuing year. On motion, it was ordered that the JOURNAL be issued

monthly during 1917, except during June, July, and August. Decision as to the size of the monthly edition and the choice of an editorial board was delegated to the Secretary and Editor.

On motion, the Editor was directed to offer the JOURNAL to senior students in agronomy at the various agricultural colleges at a reduced price for one year only, this price to be approximately the cost of publication (later fixed at $1.25).

In March, by a mail vote, the committee unanimously authorized the organization of the Illinois Section of the Society, with headquarters at Urbana. In May, a local section at the North Carolina A. & M. College was similarly authorized.

## REPORT OF THE COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

The committee have felt that it is desirable to proceed cautiously in the matter of making recommendations regarding methods of field experimentation. There are at present very few data on which recommendations could be based, and we think that the greatest service that the committee can accomplish at this time is to examine carefully the data at hand and to encourage further research along this line. We have, therefore, decided to select certain phases of the subject, to review the records of experimentation dealing with these, and to draw some conclusions if that seems justifiable, but to withhold recommendations.

Our efforts have been directed towards the consideration of questions regarding the use of check plots in field trials and the size of plot that is best adapted to obtain reliable results. The former of these has been treated by Professor Wiancko and the latter by Dean Jardine and Dr. Lyon, Dean Jardine discussing the subject from the standpoint of crop experimentation and Dr. Lyon from that of soil experimentation. In addition to this we have compiled a partial bibliography of the literature dealing with methods of field experimentation. It is hoped that this work on the bibliography will be continued by succeeding committees so that the Society will ultimately have a complete bibliography of the subject.

### SIZE OF PLOTS FOR FIELD EXPERIMENTS WITH CROPS.

W. M. JARDINE.[1]

Taylor (65)[2] found that the size of field plots in this country varied from one fortieth acre to 2 acres, the smaller ones being most common. The 150 plots at the Rothamstead, England, experiment station were found to vary in size from an eleventh to a half acre in size, the average being a little over a fifth acre. He believes "the general proposition may be laid down that the size of plots should vary inversely with the degree of uniformity of the soil." Except for breeding and selection work the plots should be "large enough to allow the unhampered use of ordinary farm machinery upon them." It is pointed out that the larger the plots the less is the error of computation.

[1] Dean Jardine desires to state that this review was prepared by Prof. S. C. Salmon and to express his appreciation of the service.

[2] Figures in parentheses refer to "Bibliography," p. 415.

"For most tests one tenth of an acre should be considered about the minimum size while the maximum would be limited largely by the extent of land available." "One-tenth-acre plots are most convenient for computing results and the area is ample for the use of most machinery."

He concludes that "the size of plots is largely a matter of convenience and local conditions." The best size "depends first upon the area of land available, second upon the uniformity of the soil, and third upon the number of plots necessary for a given experiment."

Smith (59) points out that in tests with corn the plots should be large enough to permit a fair representation of the seed under investigation. This is stated to vary with the nature of the test and no definite rule that will apply to all cases can be laid down. At the Illinois station the single or 2-row plots for variety tests have been abandoned because they seem to be too narrow for a fair test. Tall varieties shade short varieties and plants with extra strong foraging powers have an advantage over a weaker adjoining variety. The system has been adopted of planting the variety plots 5 rows wide and discarding at harvest time the 2 outside rows of every plot.

Cory (13) compared row plantings and field plots for variety tests in experiments at Dallas, Texas, and McPherson, Kans. He noted the following advantages for the row plantings: (*a*) Easier to get help for harvesting the row plantings than to secure teams to harvest the field plots; (*b*) the bundles from rows can be stored and thus prevent damage from bleaching, sprouting, shattering, etc.; (*c*) all short and weak stems are gathered better than in field plots; and (*d*) economy in land and labor. He gives it as his opinion that except for "varieties with short or weak stems, or in cases of unequal germination, insect infestations, or errors made in threshing, . . . the row plantings will furnish an accurate check for field plots."

In tests conducted at the Cornell Agricultural Experiment Station, Lyon (39) found that the mean deviation from the normal yield is considerably less for plantings in 17-ft. rows when 10 such rows represent a single test than for tenth-acre plots when each plot represents a different test. "The advantage from the small plots is not only in point of accuracy but also in the area of land required. Seven one-tenth-acre plots covered an area of 30,492 square feet while seventy of the rows required only 1,190 square feet. The use of the row method in variety testing is commended by the results of this test."

Piper and Stevenson (55) recommend the use of fortieth-acre to tenth-acre plots as the minimum for varietal and similar tests with small grain, these plots to be replicated at least twice and preferably five times. For row tests, rows 1 rod or more in length and 6 to 10 inches apart are recommended. For varietal and similar tests with corn, the minimum standard recommended is 5 rows each of 25 hills or 5 rods long, the outer two rows to be discarded.

Lyon (40), from a review of experiments dealing with experimental error in field plots and from his own experiments and those of his associates at the Cornell station, concluded that "There seems to be little gained in accuracy by using plots larger than one fiftieth of an acre in size, when the yield of crops is made the criterion. . . . For accuracy in sampling soil, the smaller the plot the better. When it is possible to give small plots careful treatment and to replicate each treatment several times, the smaller plots are preferred to large ones. . . . An area of one twenty-fifth acre of land in four widely separated plots devoted to any one test secures a much larger degree of accuracy than the same area of land in one body."

Mercer and Hall (43) grew an acre of mangolds which they harvested in 200 sections of one two-hundredths acre each and 1 acre of wheat which they harvested in 500 sections of one five-hundredth acre each. By combining these plots into larger plots and comparing the probable errors of the different sizes so obtained they were able to arrive at a comparison of the accuracy of tests conducted with different-sized plots. They concluded that the error diminishes with the size of the plot but the reduction is small when the plot grows above one fortieth acre. For practical purposes the authors recommended that in any field experiment each unit of comparison (variety, method of manuring, etc., according to the subject of the experiment) should be given five plots of one fortieth of an acre each, systematically distributed within the experimental area.

Wood and Stratton (78) investigated the error of field experiments by two independent methods. By the first method an apparently uniform area of about an acre was marked out in the middle of a field of mangels and divided into plots of one thousandth acre each. These were harvested and weighed separately. A total of 1,050 plots were harvested, but 150 on one side of the area were excluded because of markedly lower yields. These small areas were combined into larger ones and the probable error for different combinations determined. By the second method, duplicate pairs of plots in experiments reported in various publications were used. For this purpose the probable error of 400 pairs of plots, including experiments with wheat, barley, oats, mangels, swedes, and potatoes and varying in size from an eightieth to a half acre was determined. The probable error varied from 3.1 to 7 percent of the mean except for the thousandth-acre plots of mangels, for which it was 12 percent. The authors conclude that the probable error is "independent of the size of the plot employed provided this is one eightieth of an acre or larger."

Olmstead (52) reviewed the experiments of Mercer and Hall, Montgomery, and Lyon, applying to their data the method of least squares. He concluded that when wheat is grown, a number of small plots, ranging down to 0.0007 acre, is much better than the same total area in a single plot. In his opinion the data indicate that one large plot is better than one small one but no optimum size is indicated. He concludes that "the estimation of the probable errors of a large number of small duplicate plots well distributed in the area devoted to a field experiment indicates that the precision of agricultural experiments can be increased by replicating the experiments on small plots.

"Replication is urged not only for giving greater precision in experiments in which the results justify the increased labor but also for furnishing a means whereby the experimenter and his reading public can determine what reliance can be placed upon the data and conclusions of the experiment.

"Replication also lessens the uncertainties involved in the use of check plots and may decrease the total area required for the conduct of field experiments."

From observations in variety and other field tests conducted at the experiment farm at Newell, S. D., Salmon (57) concluded that greater accuracy in variety tests can be secured by dividing the tenth-acre plots (33 × 132 ft. plus 5-ft. alleys) into five plots of approximately one fiftieth acre each (6 × 132 ft.) separated by alleys of 1.6 ft., and replicating each variety five times. By this method the same area of ground was required for a given number of varieties and much greater accuracy was secured with an additional expense for labor in seeding, harvesting, and thrashing of less than 50 percent.

Barber (4) pointed out that there are proportionately more plants along the border in small plots than in large ones and since the plants on the outside of the plots are more productive than those within the plot, the error from this source is greater in small plots than in large ones where the plots are separated by cultivated or uncropped pathways. He gives no experimental data to show the optimum size of plots.

Mortenson (51) believes that from 0.005 to 0.001 hectare (about 535 sq. ft.) is the proper size of plots and states that better results have been obtained from small plots repeated often than from larger plots.

Montgomery (48) grew a plot of wheat $77 \times 88$ feet and harvested it in 224 separate plots each 5.5 feet square. The soil was of average uniformity and fertility, producing on the average about 25 bushels per acre. These small plots were combined into larger plots and the error for the different sizes so obtained was computed. It was found that "increasing the size of plot above four adjacent blocks has had very little effect on reducing variation." He states that plots $5.5 \times 16$ ft. is a very convenient size. With plots of this size "48 comparative tests per acre can be made, repeating each ten times, with a much higher degree of accuracy than when tenth-acre plots are repeated twice or three times."

In another paper (49) he concludes that "to increase the size of the block up to a certain limit rapidly decreases variability; but error cannot be indefinitely decreased by continuing to increase the size of the plot. . . . To increase the length of the row four times decreases the deviations about one half. By increasing the length of the row or the size of the block the number of repetitions necessary is decreased, but the total area required to secure the same accuracy is increased. An excellent size where land is plenty would be 2 to 4 rods in length for rows and $5 \times 16$ feet in area for blocks."

## Size of Plots for Field Experiments with Soils.

T. L. LYON.

Field experiments with crops are concerned with the soil merely as a means of producing the crops. Uniformity in the soil is the great desideratum, although other factors, such as the degree of fertility or acidity, may affect the results. As these latter factors may best be gauged by repeating the experiments on other soils, the problem in the end resolves itself into one of securing a uniform medium for any set of trials. The results are measured only in terms of crop yields or quality.

Field experiments with soils are as dependent for their success on the uniformity of the soil at the beginning of the experiment as are experiments with crops, but after the experiment is once begun the uniformity is necessarily destroyed. The results of the experiment may be measured in terms of crops or in terms of the soil itself, which is generally accomplished by the use of chemical, physical, or biological tests.

As both crop and soil experiments demand a uniform soil at the outset, any discussion of the subject from either standpoint would naturally cover much the same ground. Crop experimentation, however, includes a discussion of the use of single rows of plants, which is obviously unsuited to soil experiments. Experimentation with soils calls for the discussion of measurements of the uniformity of soil plots by other than cropping tests. Unfortunately this latter

phase of the subject seems not to have received much consideration at the hands of experimenters.

The function of this paper is to review the published investigations that are available on the subject of the relation of the size of field plot to the experimental error introduced by lack of uniformity of the soil. The review is confined to reports of experiments and does not pretend to be exhaustive.

Any discussion of the degree of accuracy to be secured by the use of plots of different sizes will naturally carry with it a consideration of the effect of replication of treatments on scattered plots, as that gives an opportunity to consider the relative effectiveness of a given area of land in one body or in scattered units.

Wood and Stratton (78) have calculated the probable errors involved in the use of plots of various sizes by taking the yields of 400 duplicate plots used in many different experiments and planted to several kinds of crops. For each pair of similar plots they have calculated the mean, and the difference between each plot and the mean. Using this as a basis they have calculated the probable error for plots of one half, one quarter, one twentieth, one fortieth, and one eightieth acres, using the formula $p.e. = 0.67\sqrt{\frac{S}{n(n-1)}}$, in which $S$ equals the sum of the squares of the deviations from the mean and $n$ equals the number of tests. The probable error for each size of plot is as follows:

| | |
|---|---|
| 45 pairs of plots each 1/2 acre | 3.5 percent. |
| 52 pairs of plots each 1/4 acre | 3.5 percent. |
| 29 pairs of plots each 1/20 acre | 3.9 percent. |
| 200 pairs of plots each 1/40 acre | 4.6 percent. |
| 75 pairs of plots each 1/80 acre | 3.1 percent. |

There appears, when judged by these results, to be no advantage in using plots of more than one eightieth acre.

Wood and Stratton also used another method for estimating the probable error arising from the use of plots of different sizes. In an apparently uniform field of beets an area of about 1 acre was measured off and divided into plots of 0.001 acre each, and at harvest each plot was weighed. In all 1,050 plots were weighed, but it was decided to reject 150 on account of their apparent lack of uniformity. The values of the probable error of these plots calculated by the method used previously is as follows:

| Number of plots. | Area. | Probable error. |
|---|---|---|
| 900 | 1/1000 acre | 12 percent. |
| 36 | 1/40 acre | 4 percent. |
| 25 | 1/28 acre | 7 percent. |
| 25 | 1/80 acre | 5 percent. |

If we consider the results obtained by both methods and discard the results from the thousandth-acre plots, which are obviously too small for soil experiments in the field, we have left eight independent results for the probable error in field experiments, which range from 3 to 7 percent. It may be deduced from this that the probable error of field experiments carefully conducted is about 5 percent. It is also interesting to note that between plots of a half acre and those of an eightieth acre the probable error is independent of the area of the plot.

The authors then show by the theory of probabilities that with a probable error of 5 percent the least significant difference between two plots is 19 percent. In other words, differences of less than 19 percent in yield would not justify conclusions as to relative effects of different treatment. In order to reduce the significant differences they advise replicating the plots and proceed to develop mathematically a table showing the number of replications necessary to obtain a certain precision in percentage difference between yields. Thus for a significant difference of 10 percent, four plots are necessary; for a difference of 6 percent, ten plots are necessary.

Mercer and Hall (43) also determined the deviations which appear in the use of plots of different areas. The areas used were selected from fields which seemed to the eye to be uniform. One of these fields was in wheat, and the other in beets. The authors employ the method of least squares for calculating the errors from plots of different sizes. The plots vary in size from one two hundred and fiftieth to one twentieth acre, from the study of which they conclude that the error diminishes as the size of the plot increases, but not proportionately, and that there is little advantage in using plots of more than one fortieth acre in area. They also conclude that it is desirable to replicate the plot treatments, but that there is not much to be gained by increasing the number of replica plots beyond five. In both of these conclusions they are somewhat at variance with Wood and Stratton.

Hall and Russell (26) divided a wheat field at the Rothamstead Experiment Station into plots of one five-hundredth acre each and harvested and thrashed each plot separately. The yields of grain averaged about 4 pounds per plot. These, when grouped at intervals of 0.2 pound produced a frequency curve that indicated a fair degree of uniformity. When the probable error for any one plot was calculated for single plots and for groups of plots, making plots of various sizes up to one tenth acre, the results were as follows:

| Size of plot. | Probable error. |
|---|---|
| 1/500 acre | 7.8 percent. |
| 1/250 acre | 6.7 percent. |
| 1/125 acre | 6.0 percent. |
| 1/50 acre | 4.2 percent. |
| 1/25 acre | 3.8 percent. |
| 1/10 acre | 3.4 percent. |

The authors conclude from these figures that there is but little advantage, in point of accuracy, to be gained by the use of plots larger than one fiftieth acre in size. They then calculated the probable error for units of five plots scattered over the area under experiment, which reduced the error to 2.4 percent, from which they conclude that each treatment should be repeated five times with plots one fiftieth acre in size in order to reach the greatest accuracy compatible with due economy of land and labor.

Montgomery (48) divided an area of wheat into 224 plots, making each plot 5.5 feet square. Each plot was harvested and thrashed separately. By combining the yields of several contiguous plots larger plots may be formed and the accuracy of larger and smaller plots may thus be compared. In this way plots of 1/144 acre, 1/36 acre, 1/18 acre, and 1/9 acre were formed and the coefficient of variability calculated from yields of wheat for three years with the following result:

| Size of plot. | Coefficient of variability. |
|---|---|
| 1/144 acre | 14.66 percent. |
| 1/36 acre | 8.95 percent. |
| 1/18 acre | 8.16 percent. |
| 1/9 acre | 7.85 percent. |

These figures indicate but little gain in accuracy by increasing the size of the plot above 1/36 acre. On the other hand if instead of increasing the number of contiguous plots a corresponding area be secured by scattering the plots systematically over the area used in the experiment the accuracy is greatly increased, as shown by the following statement:

| Number of plots. | Area thus secured. | Coefficient of variability. |
|---|---|---|
| 1 | 1/144 acre | 14.66 percent. |
| 4 | 1/36 acre | 5.51 percent. |
| 8 | 1/18 acre | 3.22 percent. |
| 16 | 1/9 acre | 2.01 percent. |

In experiments by Lyon (40), 37 hundredth-acre plots were used. These were planted to maize and all received the same treatment. The yields when plotted in a frequency curve indicated that the figures were suitable for calculating the probable error which may be expected to occur on any plot in the series. Calculated in the customary way the probable error for any hundredth-acre plot was 5.2 percent. In order to compare the hundredth-acre plots with larger ones the plots were grouped in four contiguous plots, thus giving an area of 0.04 acre. Calculated in a similar manner the probable error for any 0.04 acre plot was 4.5 percent. When the 0.01 acre plots were arranged so that every fourth plot was a check and in units of four plots scattered over the area under experiment the probable error for any treatment was reduced to 2.0 percent.

In the same paper a report is given of an experiment in which a field of potatoes was harvested by rows, each row constituting a plot of 0.02 acre. By combining these, larger plots were formed. When the data of the yields is handled in the same way as the preceding the probable errors for plots of different sizes are as follows:

| Size of plot. | Probable error. |
|---|---|
| 1/50 acre | 6.1 percent. |
| 1/25 acre | 4.8 percent. |
| 2/25 acre | 3.8 percent. |
| 3/25 acre | 3.2 percent. |
| 4/25 acre | 3.3 percent. |

In this field there is no significant increase in the probable error until the plots become as small as one twenty-fifth of an acre.

Holtsmark and Larsen (32) proceeded in a somewhat different way to estimate the errors arising from the use of plots of different sizes. They first determine what they call the true error, which is found by planting the entire area, consisting of all the plots to be tested, with a certain crop. The average for the yields of all of the plots is termed the "true value" of the plots, and the difference between this average and the actual yield of any plot is termed the

"true error." The "true errors" are used as the basis for calculating the "mean error" by means of the following formula:

$$m = \pm\sqrt{\frac{V_1^2 + V_2^2 + V_3^2 + \cdots V_n^2}{n}},$$

in which $V_1$, $V_2$, $\cdots$ $V_n$ are the true errors, and $n$ is the number of errors of which the mean error is to be determined. They proceed on the theory of probabilities that when $n$ quantities vary from a certain value through faulty observation, and when the average error of the separate quantities is $m$, the error of the arithmetic mean of the quantities will be $\pm\frac{m}{\sqrt{n}}$.

If instead of one plot for each fertilizer or other test, two plots are used, the mean error becomes $\frac{1}{\sqrt{2}} = 0.71$; if three plots are used the mean error is $\frac{1}{\sqrt{3}} = 0.58$; four plots, $\frac{1}{\sqrt{4}} = 0.50$, as great as the mean error when only one plot is used.

By experiment the authors found these values actually to be 1:0.658:0.418 instead of 1:0.71:0.50. They ascribe the discrepancies to the fact that the errors are not all accidental, as is assumed by the theory of probabilities, but that there were also errors caused by non-uniformity of the field.

The above explanation is necessary in order that the reader shall understand their method of estimating the comparative accuracy of plots of different sizes. A field with a crop growing on it was divided into 96 plots of 1/16 acre, and these grouped to make 48 plots of 1/8 acre, 24 plots of 1/4 acre, 12 plots of 1/2 acre, and 6 plots of 1 acre. The mean error for each group of plots was then calculated with the following results:

| Number of plots. | Size of plots. | Mean error. | Mean error in percentage of average yields. |
|---|---|---|---|
| 96 | 1/16 acre | 0.887 | 17.4 |
| 48 | 1/8 acre | 1.610 | 15.8 |
| 24 | 1/4 acre | 2.910 | 14.6 |
| 12 | 1/2 acre | 5.180 | 12.7 |
| 6 | 1 acre | 9.390 | 11.5 |

As compared with the other experiments cited there is a relatively larger error with the use of small than with large plots. These results are of interest chiefly because of the method used in securing them.

Olmstead (52) has worked over the data recorded by Mercer and Hall, Montgomery, and Lyon, and has calculated the probable error for any plot in Mercer and Hall's wheat and mangold fields, Montgomery's 5.5 ft. square wheat plots, and Lyon's potato rows, when the unit areas in these fields are grouped contiguously and when scattered over the field used in the experiment. He shows that all of these data indicate that the precision of field experiments may be increased by replicating the tests on small plots down to 0.0007 acre rather than by using the same area in one large plot. He says: "When many small, well-distributed duplicate plots are used, soil of all degrees of productivity is likely to be found in each group of plots, and this is the main argument for replication in field and pot experiments."

An attempt has been made by Kaserer (35) to ascertain the number of borings that are required to adequately estimate the composition of the soil of a field plot. Two plots were selected, each of which had a known history extending over a number of years previous to making the test. The previous treatments had been uniform over the entire area of the plots. Each plot was 164 feet long and 65.5 feet wide. Samples were taken to a depth of 10 inches by means of a Kopetzky borer. The borings were made on the line of the diagonals of the plots and there were nine borings in all. As the borings were equidistant on the diagonals they would be 29.5 feet apart.

The sample obtained by each boring was analyzed separately, determinations of dry substance, total nitrogen, and nitrate nitrogen being made in duplicate. While the duplicate determinations of the same sample agreed excellently well there were larger differences between the samples. This leads him to call attention to the great difficulty in getting a representative sample of the soil of a field plot and to recommend that borings should be taken on at least every square meter of surface.

An attempt was made by Allison and Coleman (1) to measure the biological uniformity of two plots of land. For this purpose 2 twentieth-acre plots were selected, one of which was in timothy and the other had produced a crop of corn previous to the test. The former was a heavy clay and the latter a sandy loam. Ammonification tests with different nitrogen carriers were made with soil samples taken at several points in each plot. The authors conclude that "where plots are uniform in character the biological variations of the soil at different points in the plot are not great, or else we are not able to detect these differences by the present methods."

## The Use of Check Plots in Field Experiments.

A. T. WIANCKO.

Although there is a considerable amount of literature on various phases of field plot experimental work with crops and soils, very little has been published concerning the use of check plots. Many of the articles that do touch upon the subject deal primarily with the application of calculation methods in reducing the experimental error in the yields secured and only incidentally refer to check plots as such. The list of references thus far gathered by the Committee is doubtless incomplete and a full review of the literature dealing in any way with check plots or checking systems is not possible at this time. Some of the references known to the Committee could not be secured for examination and review. In the paragraphs below an attempt has been made briefly to summarize the principal points in the articles referring to check plots and checking systems involving check plots of one kind or another.

Atwater (2) calls attention to the unevenness of the soil and the fact that duplicate trials seldom agree, and suggests the preliminary testing of areas intended for experimental purposes by uniform treatment for a series of years and using only such as prove to be intrinsically uniform. Where experiments are to be undertaken at once and preliminary testing is not feasible, he suggests the use of small plots several times repeated. In another part of the discussion he suggests duplicating manured plots and using not more than two or three unmanured plots for ordinary experiments.

In a later report (3), which gives full instructions for conducting field soil

fertility tests, Atwater says with reference to check plots: "It is of the greatest importance that several unmanured plots be left for comparison. For eight manured plots, two unmanured will suffice; but where there are more than that, three, one at each end and one in the middle, or, if the number is large, one in the middle and one half-way between this and each side would be advisable. You will have very little idea how uneven an apparently uniform soil may be until you make the trial."

Morgan (50) reports a study of the variation in yields on different areas in similarly treated fields of corn and wheat which were divided into a large number of small plots. By calculations based on assumed checks at a number of different intervals, it is shown that the average variation is constantly reduced with the frequency of the checks.

In his book on fertilizers and manures, Hall (24) briefly discusses the layout and management of experiment fields and recommends repeated smaller plots as being preferable to larger single ones. He further calls attention to a plan used by Dr. Sonne in Denmark, involving four repetitions of each treatment distributed around the field, as a means of reducing error.

Thorne (66), in a circular which contains detailed instructions for conducting field experiments, states regarding check plots: "A matter of great importance, too often lost sight of in field experiments, is the repetition of check plots. In the most uniform soils there will be some variation in the produce of adjoining plots from season to season. Even were the actual plant food the same, the variations in level which occur on all soils will produce an unequal distribution of moisture, and moisture may often be a more important factor in determining crop yield than plant food. The ideal system of plot experiment would leave every alternate plot as a check. Next to this comes the plan of leaving every third plot as a check, thus having a check plot on one side or the other of every plot under treatment. In fertilizer tests the check plots may be unfertilized or subjected to uniform dressings with a standard fertilizer or manure, depending upon the object of the experiment. In variety tests the check plots should be planted to a standard variety." In discussing the calculation of the increase, the author recommends the method of comparing the treated plot yield with the normal yield calculated from the two nearest checks, assuming the difference between the checks to be uniformly progressive.

Gardner and Runk (21), in connection with a report on a variety test of oats at the Pennsylvania station in 1908, discuss the checking method using a standard variety every third plot and computing the yield of the intervening varieties from a calculated check yield, assuming a uniform change in the soil from one check plot to the next.

Lyon (39) reports the comparison of wheat variety tests conducted by means of tenth-acre plots with every third plot a check, and 17-foot rows with every tenth row a check. The probable error for each checking system is calculated and found to be smaller in the row system. It is concluded that the row method may be preferable in point of accuracy as well as in requiring less space.

Lyon (40), in a report on some experiments to estimate the error in field plot tests, discusses the use of check plots at some length, explaining their use as being based upon the assumption "that the productiveness of the soil changes gradually from point to point and that consequently the natural productive capacity of any plat may be determined by its distance from two plats on either side, the natural productive capacities of which are known." Experi-

ments are cited, showing that this is not always true. It is brought out, however, that the more frequently check plots are introduced the more accurate will be the results. Different methods of making corrections by means of check plots and the use of repeated series as means of reducing error are discussed. The conclusion is reached, regarding the distribution of checks, that "the use of check plats every second or third plot secures greater accuracy than when no checks are used," but the data at hand do not indicate any advantage from the use of check plats at less frequent intervals.

Piper and Stevenson (55) discuss the various factors affecting the problem of field experiments in crop and soil studies and suggest minimum standards for each of several lines of investigation. As regards checking, different systems are recommended for different lines of work. For corn variety tests, every fifth plot or fifth row as checks and five replications in rows and two to three replications in plots are recommended. For small grain tests, every fifth row or third plot as a check and from two to five replications in plots and ten in rows are recommended. For soil fertility tests, it is recommended that every third plot be used as a check and that the whole series of plots be repeated as many times as may be required for the growing of each crop in the test every year.

In an experiment to determine the experimental error in field tests, Mercer and Hall (43) found wide variations in the yields in different parts of an apparently uniform field and conclude that a single season's results on single plots may be very unreliable and that trials should be replicated. Five replications are recommended to bring the error within 2 percent. Mention is also made of the fact that variations due to season can be checked only by repeating over a series of years.

Mitscherlich (46), in a study of the experimental error in twenty experiments, found that the error is lessened by reducing the size and increasing the number of plots (duplicate as well as control).

Montgomery (48) found that repeating ten times in small plots was much more accurate than large plots repeated two or three times and concludes that the only method of securing comparative yield tests that will meet all of the fluctuating variations is systematic repetition.

Montgomery (49) presents a considerable amount of experimental data on different systems of planting and checking in field studies with wheat. He concludes that systematic repetitions is the best way to reduce error and that ten to twenty repetitions should be made to insure a satisfactory degree of accuracy. It is also known that while having every other row a check gives the highest degree of accuracy, the total number of plots required for the same degree of accuracy is greater by this method than by systematic repetitions.

In a study of the size of plots and effect of repetition on accuracy, Mortensen (51) shows that better results have been secured from small plots repeated often than from larger single plots. It is concluded that the number of repetitions should be from eight to ten ordinarily, depending upon the number of factors to be determined by the experiment. If more than two factors are wanted, more than ten plots should be used.

Hanroth (26) discusses methods of reckoning the variation of each plat of the series from the mean of their yields. The Gauss formula is applied to various fertilizer experiments as a means of making corrections for the observed variations.

Salmon (57) discusses the need of greater accuracy in field plot experiments and with particular reference to variety tests suggests the use of the small plot repeated several times.

Salmon (58) presents some data from a variety test of barley in 1912 which was non-uniformly affected by some unknown cause, probably uneven drifting of snow, and shows that no fixed check plot system of correction could be safely applied to the results.

Olmstead (52) presents a number of different sets of data to illustrate the application of the method of least squares in computing the results of field plot experiments to a comparable basis and discusses the use of check plots and repeated plantings. In the discussion of the check plots, mention is made of the practice of having one third to one fifth of the plots as checks and it is suggested that a combination of the methods of comparing with a normal yield based on the two nearest checks and the method of comparing with the average yield of all checks be used in calculating the results to a comparable basis. From the experimental areas of the study, including several different crops, it is concluded that replication of experiments on small plots is the best means of increasing accuracy.

Wiancko (76), after a brief discussion of the use and distribution of check plots in existing soil fertility experiment fields and calling attention to the non-uniformity of the annual curve of the check plot yields, points out the fact that the check plot as usually employed, having all the produce removed from it and nothing returned, becomes poorer and poorer and that during the process of reduction of fertility the initial relations of one check plot to another may change and that finally the plots become so poor that crops either do not develop normally at all or are subject to uneven annual fluctuation caused by various unfavorable climatic conditions, plant diseases, and insect injuries to which their unthriftiness makes these plots especially subject. The question is then raised as to whether it would not be wise to maintain the check plots in a reasonable state of fertility by means of a uniform manurial treatment calculated to produce at least fair yields of all the crops in the rotation.

Pritchard (56) presents data from sugar-beet experiments showing the effects of check rows at different distances and of repeated plantings. It is shown that both frequent checks and several replications should be used to secure reasonable accuracy.

Stockberger (63) applies different methods of calculation to the reduction of error in connection with a test of thirty rows of hops and concludes that the methods are of little value, as fresh errors may be produced. These errors may be reduced by corrections for imperfect stand and by replication.

Surface and Pearl (64) discuss the variability in the fertility of the soil as a factor in field experiments and propose a method of calculation to correct for such errors with special reference to crop variety tests. The method involves the calculation by the contingency method of the probable yield of each plot on the supposition that they have all been planted with a hypothetical variety whose mean yield is the same as the observed means of the field. This calculated yield is then used to correct the actual yield of the plot to the mean of the field. The ordinary check plot method is not considered satisfactory.

## CONCLUSIONS.

The investigations here reviewed seem to admit of the following conclusions:

The probable error for any one plot decreases as the size of the plot increases.

For any given area devoted to a test of a single treatment the probable error is less if this area be divided into sub-areas and scattered over a field than if the treatment be applied to one single body of soil. Furthermore the probable error appears to decrease with increased subdivision of the area down to very small units (possibly 0.001 acre).

For the same reason greater accuracy may be secured by using scattered treatments on small plots than by one treatment on a large plot even when the small plots do not cover as much land as does the large plot, but the ratios involved in this conclusion have not been definitely worked out.

Experimental evidence appears to leave no doubt as to the possible accuracy of replicated row plantings as compared with single field plots when equal areas are used for each, and even when smaller areas are used for the row plantings, but here again no definite ratios are available.

While there are very few data on the frequency of borings necessary to secure accuracy in sampling field plots, such data as are available indicate that it is difficult to secure an accurate sample and that borings should be taken at close intervals of space.

Experiments in the use of check plots seem to indicate that the usefulness of these plots increases with the frequency with which they are distributed among the test plots. There are not sufficient data, however, to guide one in estimating how frequent their use should be in order to obtain any desired degree of accuracy.

## SUGGESTIONS.

The committee do not desire to recommend to the Society that it adopt any particular size of plot, number of replications, or method of handling check plots. We feel that the subject has not been sufficiently developed to make it advisable for the Society to place itself on record with respect to any one procedure as opposed to the many possible ones. We strongly urge, however, that investigation of the whole subject of field plot trials, and particularly that phase of it that concerns the size of plots and handling of check plots, be conducted by members of the Society.

More data should be secured on the probable error involved in the use of plots of different sizes and the number of replications required to reduce the error to any desired degree of accuracy. With a sufficient amount of such data at hand it will be possible for the experimenter to calculate exactly how many replications he must have with plots of a given size in order to get significant differences in yield of crops. It is quite evident that if an experiment is not conducted with sufficient accuracy it is worthless and it would have been better not to have attempted it. If, as stated by Wood and Stratton, an experiment on single tenth-acre plots requires differences in yields of 20 percent in order to insure that the differences are due to the treatments, it is very evident that a considerable number of our field plot tests do not admit of the interpretations that have been placed upon them.

The relative accuracy of row plantings and plots is a subject that requires investigation. The practice of row plantings seems to be subject to error from the effect of adjacent rows that contain more vigorous or less vigorous plants. How to meet this difficulty is a problem for the experimenter.

Very little work has been done on securing representative samples of soil from field plots. Refinements of analytical methods are useless if the samples do not represent the average soil of the plot within at least rather narrow limits of error.

In the study of the use of check plots much experimentation must be done before we shall know how best to scatter and treat these plots. There is the question whether checks shall be used only in the same number and manner as the replicated test plots, or whether they shall be used more frequently. If they are to be used more frequently, at what intervals shall they be distributed? What method shall be used for calculating the yields of test plots from the checks? Finally, there is the important question regarding the maintenance of fertility of the check plots in order to make a fair comparison with the test plots.

All of these problems must be studied. They cannot be decided by vote of the Society. But this Society represents the men who are to solve these problems if this country is to do it. Let us then devote our energies to this work and let every experiment station that is conducting field experiments use some of its land and resources to investigate at least one phase of the subject during the coming year.

It is not a simple matter for a committee to arrange for a systematic plan of cooperative experimentation with methods of field experimentation. The equipment required is too elaborate. There is probably no time when many experiment stations could conduct experiments on any one phase of the subject, except possibly on the number of borings required to adequately represent the soil of a plot. The matter cannot be handled like a chemical analysis for which almost any laboratory is equipped.

It seems likely that it will be necessary to leave the work to voluntary effort on the part of agronomists, but the Society can continue to do much to stimulate activity in this direction. The present interest should not be allowed to subside. It is through the JOURNAL of the Society, discussions at the meetings, and work of the Committee on Standardization of Methods that this Society can operate. All of these agencies should be used to the fullest extent. The committee feels that the agronomists of the country are alive to the necessity of improving methods of field experimentation and that by continuing the active participation of the Society in the work a mass of data will be collected that will eventually make it possible to compute the experimental error for any desired procedure and thus to insure the accuracy of the results.

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## REPORT OF THE COMMITTEE ON VARIETAL NOMENCLATURE.

The Committee on Varietal Nomenclature of the American Society of Agronomy has now been in existence for six years, and feels justified in reporting that during this period considerable interest has been developed in the problem of working out the classification of our principal crop plants and the adoption of standard names. A summary of results was reported at the last meeting. The time has now arrived when we should take some definite steps in adopting a Code of Nomenclature, and also consider the best means of making practical use of standard names.

### WORK OF OTHER SOCIETIES.

Several societies interested in economic plants have been at work in recent years on the problems of nomenclature in their own field and we may gain some information from their experience. The American Pomological Society began work many years ago. This work has been mostly in the hands of men connected with the United States Department of Agriculture. A large amount of systematic work has also been done at the New York State Experiment Station. Several publications have already appeared.

The old Society of American Florists years ago established the publication of a register, in which all new varieties were listed with the introducer's description. Some attempt was made to avoid the use of synonyms.

Several specialized floral societies, as the Peony Society, the Rose Society, etc., have developed, and some of these groups have undertaken the work of classifying and naming the varieties in which they are especially interested. More recently the Vegetable Growers' Association of America has suggested rules for naming garden vegetables and considerable work has been undertaken.

With regard to the nomenclature of fruits and vegetables, Prof. L. C. Corbett, horticulturalist in charge of the Office of Horticultural and Pomological

Investigations of the U. S. Department of Agriculture, writes as follows in a recent letter:

"The Department of Agriculture, and especially the Office of Horticultural and Pomological Investigations has had much to do with bringing the nomenclature of fruits and vegetables up to its present degree of perfection. You are of course familiar with the early work of Ragan in regard to the nomenclature of the apple and of the pear. Prof. Lake has in recent times been giving a great deal of attention to the nomenclature of the peach, thus adding one more to the list of fruits which have been gone over carefully from the standpoint of nomenclature.

"In our recent work we find that the code as it exists at present does not entirely meet the requirements of the case, and I understand that the Nomenclature Committee of the American Pomological Society, which has always cooperated heartily in this work, expects to take under advisement next year the feasibility and practicability of making some important changes. I enclose a copy of a proposed code referred by the Society at its recent meeting to the Committee as a basis for revision of the rules previously in force. The matter of types and type material on which varietal descriptions ought to be based is one that should receive careful consideration. In fact, I do not believe that stability in any system of nomenclature can be attained unless the type idea is incorporated.

"The work which we are specifically doing is first, to bring together a comprehensive list of all names which have been applied to varieties of any particular group of fruits with the original descriptions to determine as far as possible their correct application, whether they are local names or catalog names. More recently, Prof. Lake has been giving a great deal of attention to the names of varieties as published in trade catalogs and has been endeavoring to standardize the characterizations of the varieties, for as we see it, catalogs do not describe our commercial varieties. In this work we have had splendid cooperation from the nurserymen and catalog makers, and we feel that a very decided step has been made in handling this feature of the work.

"Vegetable nomenclature is much less advanced and the most we can say for it at the present time is that members of our force are now engaged in determining the synonymy of names of varieties used in the trade and an effort is being made, in fact, resolutions have been passed by the Vegetable Growers' Association of America, practically adopting a code similar to the one adopted by the American Pomological Society a number of years ago. This, as I have it in mind, practically presents the present status of the fruit and vegetable nomenclature work."

Professor A. C. Beal of the New York State College of Agriculture has carried out much of the detailed work in connection with the classification of floral groups, and he has been asked to give a brief review of experience gained in this field. The work has been carried out in each case in cooperation with the particular society representing the special group of plants under study. Dr. Beal's statements are here presented.

"Some years ago the trial grounds of the American Peony Society were established on the grounds of the Department of Horticulture at Cornell University. This work was cooperative on the part of the American Peony Society and the Department of Horticulture. It was known that there were hundreds of varieties of peony names in the catalogs and trade lists of Ameri-

can and foreign growers. The nomenclature, however, was in a state of confusion. The American Peony Society solicited the plants and a large collection, supposed to represent more than 1,600 varieties, was brought together at Cornell. A search of the literature was made in order to determine when the different varieties were introduced into the trade. This information was secured for the purpose of determining the priority of names. When the plants bloomed a committee of two or three men representing the Society came to Ithaca and assisted the representative of the Department of Horticulture in studying and describing the varieties. In one case a variety was received under as many as seven different names; there were many cases of two or three synonymous names. When the work was completed it was found that the collection represented less than 500 different varieties. As the descriptions were made the plant from which the description was taken was tagged and later lifted and planted in a separate plot. Owing to the longevity of these plants, we have at present growing on our grounds the identical plants from which the official descriptions were made. The results of the work were published in bulletins 259, 278, and 306 of the Cornell station.

"When the American Sweet Pea Society was organized in 1909, one of the first objects which it hoped to attain was the reduction of the number of sweet pea novelties. At that time from 50 to 100 varieties were appearing each year. A new type of sweet pea had been recently introduced and this type had an unusual tendency to produce seed sports. The result was that similar variations occurring on the grounds of different growers were named and later introduced into the trade. It was not infrequent to find the same variation appearing in the same year under four or five different names. A trial ground was established at Cornell on the same general plan as the peony trial grounds. The seed has been contributed by American and foreign seedsmen. In past years we have grown from 100 to 500 supposed varieties each year. We have endeavored to ascertain the synonyms and also to point out all cases where the differences between varieties are slight. We have not had the assistance of a committee from this society as in the case of the peony society. The work has been done by the investigation staff of the Department of Floriculture. It has not been so necessary to have a number of persons carry on the study, as in the case of the peony, for the reason that the sweet pea blooms over a longer season, and, therefore, it is possible to secure the detailed notes necessary for the preparation of full and complete descriptions. The writer has been chairman of the Committee on Nomenclature of the American Sweet Pea Society, and, naturally, all applications to register new varieties have been referred to the committee before registration was permitted. The results of this work have been published in Cornell station bulletins 301, 319, 321, and 342.

"When the American Gladiolus Society was organized in 1910, it asked the Department to undertake trials with gladioli. The nomenclature of this flower was in an extremely confused state, for the reason that many persons had been producing seedlings and naming the meritorious varieties; then they sold in mixtures all of the supposedly inferior seedlings. It appears that when some of the mixtures fell into the hands of certain growers, on other soils, under different conditions, the varieties were so improved as to be worth naming. Sometimes more than one grower would pick the same novelty and name it. In other cases the named varieties included in mixtures were selected and given other names. Of course, the grower was usually innocent of any wrongdoing,

but the practice, nevertheless, tended to multiply the number of names and bring about confusion. We have tested several hundred varieties on the trial grounds here, have made careful descriptions of them, and the results have been published in extension bulletins 9, 10, and 11. As chairman of the Nomenclature Committee of the gladiolus society, we insisted that a variety offered for registration with the society shall be tested on the trial grounds in order to determine whether it is distinct from existing varieties before the committee will approve it for registration.

"The number of roses introduced each year has during the last fifty years varied from 40 to 150 annually. There is usually little difficulty about renaming of greenhouse roses, for these are usually exhibited before the American Rose Society before they are introduced. The attention of the cut flower growers must be secured before it is possible to sell any large number of plants to a single grower; also, owing to the fact that a large investment is necessary before a man can grow and propagate a new variety in large numbers, men who make a business of sending out novelties are extremely cautious in buying new varieties from the originator. In the case of garden roses, however, the situation is very different. It is possible to multiply a new variety rapidly by means of buds and by selling one or two plants to a large number of individuals to secure a wide distribution of a novelty. In order to place some check on this practice as well as to secure information as to the adaptability of varieties to different soils and climate, trial grounds for roses have been established in different parts of the country. One of these is located on the grounds of the Department of Floriculture at Cornell. Another object which was aimed at on the part of the Nomenclature Committee of the American Rose Society was to try to get the originators and introducers of new varieties of roses to apply short, serviceable names to novelties. The Committee sought to have a rule adopted, whereby extremely long names now in use could be reduced in length. I am sorry to say, however, that little was accomplished in either of these directions. My own feeling is that a name should consist of one or two words and not more. No publications have been issued giving the results of the rose trials at Cornell.

"The above is a brief outline of the different trial grounds that we have established in connection with the American Peony, American Sweet Pea, American Gladious, and American Rose societies. I will say, however, that we are carrying out somewhat similar work with perennial phlox and with iris. In these cases, however, the work is in charge of graduate students. The plants are contributed by interested growers and the work is conducted on the same general lines as the trial ground work above indicated, the chief difference being that there is no special society backing these two lines of work. If publications are issued, we shall, however, note all synonyms in connection with the descriptions of the different varieties. We hope that the work may be valuable, if published, in clarifying the nomenclature of these plants.

"In all this work, in order to determine the priority of names we have found a complete set of catalogs of nurserymen and seedsmen extremely valuable. We do not find that American horticultural and agricultural publications to any large extent publish descriptions of the new varieties of plants. Use, however, is made of the files of journals as well as the catalogs in preparing lists of varieties of the different plants we have worked with. In all this work it is desirable in connection with the name of the variety to know the name of the

originator, the introducer, the year of introduction, the parentage if recorded, and as complete a description as can be ascertained. Having this information it is possible to work out questions of priority of names. The next step in the work is usually to make a list of the names of all the varieties cataloged by the trade. When such a list is prepared the investigator, the nomenclatorial, or the trial ground committee endeavors to secure from the growers a stock of all the different varieties, giving particular attention to suspected synonymous varieties. When the stock is received, if possible, a systematic arrangement is made of the varieties when planting. For instance, in the case of flowers, we try to arrange them so as to bring similar colors together. Crops that are planted annually lend themselves to this plan more readily than perennial plants, which, when planted are expected to remain in one position for several years. However, such an arrangement facilitates comparative studies.

"In making descriptions of varieties, it is desirable that all descriptive notes be complete. In our work we have found a descriptive blank desirable for the reason that all of the points are passed upon when such an outline is used. All such notes, of course, should be supplemented by photographs, herbarium specimens, etc.

"In publishing the results, whenever possible, an outline, a key, or the arrangement of the varieties in some systematic order is extremely desirable. The arrangement of the varieties in this way tends to bring together varieties which are more or less similar and at the same time emphasizes the special points which separate one variety from another.

"In all this work we usually plan to make some sort of a brief general report regarding the work, to the societies interested, at their annual meeting. This keeps the organization in touch as to what is being done and adds to their interest in the work while it is in progress; in fact, we regard it as very necessary for a representative of the department to meet and take part in the meetings of the organizations interested in our cooperative work. All the plants which we use in the work have been contributed. In the case of novelties it is extremely important that the stock be safeguarded so that assurances can be given the introducers that no plants will be distributed from the trial grounds. If this confidence in the work is secured, we believe that no special difficulty will be experienced in getting the new varieties. In the course of our work we have had many varieties sent to us before they were introduced in the trade; in some cases before they were even named. In the case of gladioli our opinion has been frequently asked as to the merits and value of a variety and we believe that, taken as a whole, the work of the department along these lines has accomplished a great deal in reducing the number of new varieties which were inferior to existing varieties. In some cases, however, it has been impossible to get certain growers to contribute stock and in order to make this kind of work an absolutely complete success, the department or the trial grounds should have some funds which would enable it to purchase the few varieties which it needs in order to make its test complete. In all the work we find it necessary to emphasize constantly the point that we are not attempting to determine the value of a variety for any large section of the country, but that we are testing the varieties side by side under as nearly uniform conditions as we can secure in order to determine whether they are distinct or not."

* * * * * * * *[1]

[1] EDITOR'S NOTE.—This portion of the Committee's report is followed by the Rules of Nomenclature adopted by the American Rose Society, the Code of Nomenclature of the American Pomological Society, and the Report of the Committee on Nomenclature and Varieties as adopted by the Vegetable Growers' Association of America. Lack of space forbids the publication of these documents here, but they are filed as a part of the Committee's report in the Office of the Secretary-Treasurer.

## THE NOMENCLATURE OF FIELD CROPS.

Last year, the Committee on Nomenclature, at the annual meeting held in Washington, proposed two plans for establishing and supervising the work on nomenclature in farm crops (Jour. Amer. Soc. Agron., 8: 392). The proposals were as follows:

1. That "certain qualified individuals might be chosen by the Society, each of whom would supervise the registration of some particular crop," or

2. "The United States Department of Agriculture might be asked to provide a specialist, whose duty is would be to care for this work and promote the general adoption of the classification when once established."

The Committee put forth these two suggestions to furnish a basis for discussion, without feeling sure which was best, or whether either would be practicable. At that time, the Society decided to take the matter under consideration for a year, with the hope that some practical plan might be adopted at the present meeting.

After further consideration it appears to the Committee that there are three groups of individuals that ultimately must be brought into cooperation in order to work out and establish the use of standard names. These three groups consist of:

*a*. The agronomists and specialists on field crops, who must be depended upon largely to work out the classification and the proper system of naming, and ultimately supervise very largely the adoption of these names.

*b*. The seed trade, which must be brought into hearty cooperation if there is to be any general and practical use made of the naming system.

*c*. The farmers of the United States, who grow the crops, and who must be brought in time to realize the value of using only standard names and recognized varieties.

It would appear that the first group, the agronomists and specialists, must do the preliminary work. It will probably take five to ten years before we will have satisfactory classifications worked out for the different economic crops, and also it will take many years before the agronomists of the country have sufficiently acquainted themselves with the different types and groups so they can be of material aid in assisting farmers in the identification and naming of varieties. Until the classification is worked out and the agronomists themselves are familiar with the systematic work, we can not hope to do very much with the other two groups, the seed trade and the farmers, in advancing this work. It would seem, therefore, that the principal work during the next five or ten years for any committee appointed at this time, would be with the agronomists. At the same time, the committee should get in touch with a committee representing the American seed trade, as it will probably take several years before the seed trade would be ready to cooperate fully in the estab-

lishment and use of standard names. In fact, we cannot make very much progress with the seed trade, except in an educational way, until our standard classifications are fairly well worked out. However, it would seem desirable to have their cooperation while this work is under way, and steps should be taken at once to get in touch with the leaders of the American seed trade.

The third group to be interested is the farmers. It will probably take educational work for a long time before the farmers can be brought fully to realize the importance and need of using standard names. Not very much in the way of a campaign, however, can be undertaken until we have progressed farther with our own work. Nevertheless, we should be looking to the time when a campaign can be undertaken among the farmers of the country for the use of standard names, and some preliminary plans for this work should be considered.

It, therefore, seems to the Committee that the two matters which it might be best to take action on at this meeting would be:

(1) The adoption of some rules of nomenclature, so that the systematic work may be carried out; and,

(2) The appointment of a committee to undertake cooperation with the agronomists, American seed trade, and the farmers, looking toward the development and practical use of the work.

We, therefore, propose for your consideration, the following motion:

*That the American Society of Agronomy appoint a committee, which shall act in cooperation with the American seed trade and any other agencies to secure uniformity in rules and practices of varietal nomenclature and registration.*

In the preparation of a classification, one of the first matters to be settled is some general principles or rules of nomenclature.

The botanists, zoologists, and workers in other fields of natural science long ago adopted codes of nomenclature, but before universal codes were adopted considerable confusion had arisen in the practice of assigning names.

The pomologists, certain groups representing different phases of floriculture, and also those interested in vegetable crops have already adopted general rules of nomenclature, and it would seem well if all interested in the naming of economic crops could follow the same general principles.

Two years ago when Dr. Etheridge published his "A Classification of the Varieties of Cultivated Oats," he was interested primarily in working out a classification, and in so far as names were concerned, used in each case the name that appeared to be applied most frequently to each variety. Messrs. Carleton R. Ball and J. Allen Clark are now prepared to publish the first part of their classification of wheats and have drawn up a proposed Code of Nomenclature. The Committee, therefore, presents this Code, somewhat revised, and asks the Society to consider it in detail and make some provision for the adoption of a permanent code.

## Code of Nomenclature for the American Society of Agronomy.

The following rules governing the naming of varieties of crop plants are hereby proposed for adoption by the American Society of Agronomy, at the annual meeting, November 13, 1917.

1. Eligibility to Naming. No variety shall be named unless (*a*) distinctly

different from existing varieties in one or more recognizable characters, or (*b*) distinctly superior to them in some characters or qualities, and (*c*) unless it is to be placed in commercial culture.

2. PRIORITY. No two varieties of the same crop plant shall bear the same name. The name published (see paragraph 4) for a variety shall be the accepted and recognized name except in cases where it has been applied in violation of this code.

   *A*. The term "crop plant," as used herein, shall be understood to mean those general classes of crops which are grouped together in common usage without regard to their exact botanical relationship, as corn, wheat, sorghum, cotton, potato, etc.

   *B*. The paramount right of the originator, discoverer, or introducer of a new variety to name it, within the limitations of this code, shall be recognized.

   *C*. Where the same varietal name has become thoroughly established for two or more varieties, through long usage in agronomic literature, it should not be displaced or radically modified for either one, except where a well-known synonym can be substituted. Otherwise, the varieties bearing the same name should be distinguished by adding some suitable term which will insure their identity.

   *D*. Where several well-established names are used for the same variety, the list of synonyms shall be submitted to some committee of the American Society of Agronomy. This committee shall choose the name which it deems most suitable, observing the established Code of Nomenclature.

   *E*. Existing American varietal names which conflict with earlier-published foreign names for the same or different varieties, but which have been thoroughly established through long usage, shall not be displaced unless long-used and available synonyms exist.

   *F*. It is recognized that certain strains of varieties may occur, which do not differ from a standard variety in recognizable characters, but may differ in yield, adaptation, or quality, and are entitled to recognition by a distinct name. Such strain shall be given a new name, but the name of the type variety in parenthesis should follow.

3. FORM OF NAMES. The name of a variety shall consist of a single word, except where it conflicts with Rule 2, *C* or *E*.

   *A*. Varietal names shall be short, simple, distinctive, and easily spelled and pronounced.

   *B*. A varietal name derived from a personal or geographical name should be spelled and pronounced in accordance with the rules governing in the case of the original name.

   *C*. The name borne by an imported foreign variety should be retained, subject only to such a modification as is necessary to conform it to this Code.

   *D*. The name of a person should not be used as a varietal name during his lifetime. The name of a deceased person should not be so used except by the official action of this or other competent agronomic bodies. Personal names in the possessive form are inadmissible.

*E.* Names of stations, states, or countries, in either the nounal or adjectival form, should not be used as varietal names, except in unusual cases where the name is well established.

*F.* Such general terms as hybrid, selection, seedling, etc., should not be used as varietal names.

*G.* A number, either alone or attached to a word, should not be used as a varietal name, but considered as a temporary designation while the variety is undergoing preliminary testing.

*H.* Names which palpably exaggerate the merits of a variety shall be inadmissible.

*I.* In applying the provisions of this rule to varietal names which have become firmly established in agronomic literature through long usage, no change shall be made which will involve loss of identity.

4. Publication. A varietal name is established by publication. Publication consists (1) in the distribution of a printed description of the variety named, giving its distinguishing characters, or (2) in the publication of a new name for a variety properly described elsewhere; such publication to be made in any book, bulletin, circular, report, trade catalog, or periodical, provided the same bears the date of issue and is distributed generally among agronomists and crop growers; or (3) in certain cases the general recognition of the name for a commercial variety in a community for a number of years may be held to constitute publication.

*A.* Where two or more admissible names are given to the same variety, in the same publication, that which stands first shall have precedence.

5. Registration. After a classification is made, and names assigned according to the Code, and the same has been officially adopted by this Society, no new names shall be recognized by the Society except by registration.

Registration shall consist in the introducer submitting to the Secretary of the American Society of Agronomy, or some properly authorized committee, a sample of seed, together with a full statement and evidence setting forth reasons why the variety is entitled to a new name. The Society (or committee) shall then have sufficient time in which to grow the crop in trial grounds and thoroughly examine the claims before reporting on the new name.

6. Citation. In the full and formal citation of a varietal name, the name of the author who first published it shall be given, when the same can be determined.

7. Revision. No properly published varietal name shall be changed for any reason except conflict with this code, nor shall another variety be substituted for that originally described thereunder.

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Pages 265–312, November 1, 1918.
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## ERRATA.

Page 25, Table 2, column headings "Hard" and "Soft" are reversed throughout.

Page 83, name of author of paper is Albrecht, not Aldrecht.

Date of issue of No. 4 should be April 25, 1918.

Plate 4, facing page 151, figure 2 is reversed.

Page 180, line 7 was carried down with footnote 2 and second line of this footnote precedes the first.

Page 280, line 8, and page 281, line 1, read "Plate 9" for "Plate 7."

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VOL. 10. JANUARY, 1918. NO. 1.

# VARIATIONS IN SEED TESTS RESULTING FROM ERRORS IN SAMPLING.[1]

O. A. STEVENS.

## INTRODUCTION.

Little attention appears to have been given to careful study of the accuracy of seed testing. Some experiments have been made during the past few years by sending to different laboratories samples drawn from a common bulk. The results of one of these has been published (Stone, 1913),[2] but so far as the writer could find from available literature no attempt had been made to analyze the fundamental factors to which variations are due. In this paper the results are presented of some investigations conducted during 1914 and 1915 when routine duties were not pressing.[3]

## CAUSES FOR VARIATION.

Variations in the results of seed testing are fundamentally of two kinds, and are to a great extent impossible to avoid. One is purely mathematical, the other personal or to a large extent economic. The direct causes may be listed as follows:

[1] Contribution from the Department of Botany, North Dakota Agricultural College. Received for publication May 14, 1917.

[2] Bibliographical citations in parentheses refer to "Literature cited," p. 19.

[3] The author is indebted to Prof. I. W. Smith for assistance with the mathematical portion of the work. Credit is also due student assistants as follows: Mr. M. S. Hagen for all of the germination work except two lots of 50 each; Mr. A. M. Christensen for the series of alfalfa purity tests and two of germination; and Mr. Sidney Hooper for one series of purity tests of flax.

| In Purity Tests. | In Germination Tests. |
|---|---|
| Imperfect mixing. | Imperfect mixing. |
| Effect of random sampling. | Effect of random sampling. |
| Errors in weighing. | Errors in counting. |
| Effect of personal selection. | Effect of personal selection. |
| Errors of identification. | Improper conditions for germination. |
| | Special conditions of the seed. |

Considering a sample from its point of origin the first source of variation is in drawing a small sample from a large bulk. The accuracy with which this sample represents the bulk depends upon the uniformity of the latter. This would depend upon the uniformity of the field or whether different lots had been mixed to make up the stock. When samples are drawn and mailed by various parties, there is greater possibility of variation than if all could be taken by the same person. When the analyst receives the sample and takes from it a standard sample for analysis the same factors are again operative.

Before the standard laboratory sample is taken, the entire lot should be mixed as thoroughly as possible. If the seed has been well cleaned, it is doubtful if any mixing is necessary. In poorly cleaned seed there are usually elements of different nature which tend to collect at certain places, such as sand, fine dirt, or small seeds at the bottom, and broken stems, etc., at the top. In such samples it may be difficult to make an even mixture, and it is desirable to separate such materials roughly from the entire sample. It may be observed that in such cases the error in drawing the sample from the bulk is likely to be large, and a careful analysis is scarcely worth the while.

After a sample has been mixed as well as possible, a small portion will not accurately represent the entire amount. If, for example, we take one seed out of a lot of one hundred which are half of one kind and half of another, it will give no estimate of the proportions of the mixture. As we take a larger number, the degree of accuracy increases, but can not be perfect unless the entire number is used. This is what is here referred to as fundamentally a source of mathematical error. This error can not be avoided, but it is possible to determine its approximate limits under given conditions and thus make allowance for it.

There is a certain amount of personal error in weighing out a standard sample for analysis, or in counting a certain number of seeds for germination tests, but this is an occasional factor rather than a constant one, as are most of those under consideration.

The error of personal selection is of considerable importance. In germination work it may be a tendency to pick out the better seeds.

There should, of course, be a standard method which would prevent this, yet it is not entirely possible. The seeds for germination should be selected from the pure seed after the purity test has been completed; but the length of the germination period is the factor which determines the time necessary for a report. Under the usual relation of amount of work to the equipment of the laboratory, time is saved by starting a germination test at once.

There is in nearly every sort of seed an indefinable line of separation between pure seed and inert matter, *i. e.*, shrunken seeds, broken seeds, and grass florets without caryopses. One may make an arbitrary division, but there will be cases coming so close to the line that they might be placed on either side. For instance, if half a seed be placed with the inert matter, and more than half with the pure seed, there will be found individuals that are not readily placed. A single instance of this in case of flax will make a difference of 0.02 percent of 10 grams. With wheat a single such grain would amount to 0.05 percent of 30 grams.

With grasses we may consider florets without caryopses as inert, but they occur in all degrees of development and are not always easily placed in either one or the other class. It should be noted, however, that these things occur most frequently in low-grade seed, in which small errors are not of great consequence.

The error of identification should not be of consequence in most cases, but there are instances where it is likely to be. We may simply mention, in passing, the difficulty of separating such seeds as alfalfa and sweet clover, meadow fescue and perennial ryegrass, species of bluegrass, species of Agropyron, etc.

The variations so far discussed apply to both purity and germination tests. There are also causes of variation peculiar to the latter, such as methods of testing and various factors modifying the condition of the seed. Certainly, unusual variations may be expected if the temperature and moisture conditions of the germination chamber are not adapted to the seed. The failure to secure satisfactory results by handling bluegrass or other small and slowly germinating seeds by the same methods commonly used for clovers or cereals is a good example of this. Seeds not sufficiently aged for prompt germination may respond better to conditions somewhat different from those usually employed for that kind of seed. Fresh seed of lettuce is one example which has caused considerable trouble in this way. Barley and oats slightly damaged by exposure to water or frost have also been a source of difficulty.

By the economic factor is meant the lack of funds to secure proper equipment or to employ workers of sufficient ability and training.

If the results of a series of analyses of samples drawn from a carefully mixed bulk and submitted to a number of laboratories are examined (Stone, 1913), the effect of these two primary factors of error is readily seen. The mathematical variation may be readily demonstrated from some of the germination tables, as will be shown later in connection with the experimental data presented. From an inspection of the purity table of bluegrass or orchard grass it may be seen that some reports give an unusually high percentage of pure seed and a correspondingly low percentage of inert matter. This is no doubt due to the inclusion in pure seed of the florets containing no caryopses. This may have been due to insufficiently trained analysts or to lack of equipment (vertical air blast separator, etc., without which such separation is quite difficult). From the table of bluegrass germination we note some very low results and some blanks probably due to a lack of equipment.

Much of the personal factor depends upon experience, not only general, but with an individual class of seeds. The workers of a laboratory in a State where a certain crop is grown little or not at all can not be expected to be as familiar with the seeds of that crop as those who have constant occasion to examine them.

## Experiments with Germination Tests.

The work here described was undertaken to determine the mathematical error in germination tests. The general plan was to make a series of 50 tests from one lot of seed and to calculate the standard deviation and probable error, these tests being made simultaneously by one person.

To reduce the sources of variation as much as possible, it seemed desirable to make a series of theoretical tests. A sample of seed to be tested for germination may be regarded as a mixture of two sorts, the one viable, the other not. The result then depends upon the perfection of the mixture and the chance of selection in a given number.

After some preliminary experiments a white-seeded kafir was selected as best suited to the purpose. Part of the seed was stained with Delafield's hæmatoxylin, the alcoholic solution being used in order to prevent, as far as possible, any change in the seed.

The first question was to determine what mixing was necessary. For this purpose 55 grams of each color were placed together and poured from one dish into another. Small pans holding several times

this amount were used and the seed poured from one to the other at the rate of fifty times per minute, the pans being about 6 inches apart. This process was repeated 25, 75, and 200 times and then the series repeated with the results shown in Table 1.

TABLE 1.—*Probable error in selecting 100 seeds from a mixture of equal parts of two sorts.*

| Number of trials. | Mixed 25 times. | Mixed 75 times. | Mixed 200 times. |
|---|---|---|---|
| First | 3.10 | 2.88 | 2.83 |
| Second | 3.05 | 2.83 | 2.82 |

The results of the trials are very close, in fact remarkably so, considering the differences in later experiments. It is rather surprising also how little difference appears from the longer continued mixing. In the following work 75 mixings were made, the operation being as nearly uniform as possible throughout the series. In counting out 100 seeds the practice followed was to pour the entire lot upon the work table and, by placing a hand on each side, draw out one end

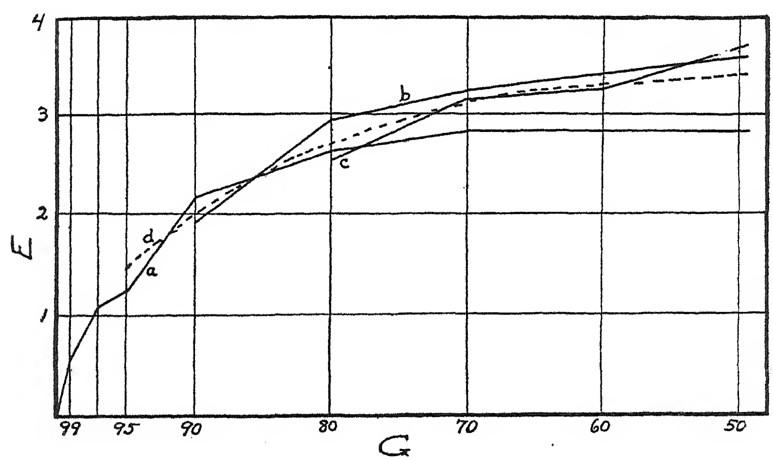


FIG. 1. Graph showing probable error in selecting 100 seeds from mixtures of different percentages. *G,* Percentage of germination; *E,* percentage of probable error; *a,* no hard seed present; *b,* 5 percent dead, the remainder hard; *c,* 10 percent dead; *d,* from Table 12 (Rodewald, 1889, p. 110).

of the pile to a narrow point. It would be preferable to have a mechanical means, such as weighing out the number. This was not used in the present case on account of the impossibility of taking just 100 seeds and the work involved in calculating odd numbers.

The method used should obviate the possibility of unconscious selection.

The second problem was to determine the error for a given percentage. In a 100 percent stock there could be no variation. As the percentage decreases from this point we may expect the variation to increase until 50 percent is reached, then decreasing again to zero. In actual tests the poorly germinating seed might show a comparatively greater variation on account of failure to respond to slightly varying conditions.

A series of mixtures was prepared and carried through with the results shown in Table 2. Inasmuch as the hard seeds of legumes introduce a third factor, two additional series were run, using 5 and 10 percent respectively as dead, the remainder being considered hard (dead represented by seeds colored with an alcoholic solution of erythrosin).

TABLE 2.—*Probable error in selecting 100 seeds from mixtures of different percentages.*

| Percentage calculated viable. | Error in viable series. | | | Error in hard series. | | Error in dead series. | |
|---|---|---|---|---|---|---|---|
| | With 0% hard. | With 5%. dead. | With 10% dead. | With 5% dead. | With 10% dead. | 5%. | 10%. |
| 50 | 2.88 | 3.63 | 3.67 | 3.60 | 3.14 | 1.92 | 1.98 |
| 60 | 2.89 | 3.42 | 3.29 | 3.44 | 3.11 | 1.84 | 2.27 |
| 70 | 2.91 | 3.24 | 3.13 | 3.08 | 2.98 | 1.55 | 1.94 |
| 80 | 2.69 | 2.95 | 2.60 | 2.38 | 2.07 | 1.14 | 1.98 |
| 90 | 2.22 | 1.95 | | 1.36 | | 1.28 | |
| 95 | 1.30 | | | | | | |
| 97 | 1.15 | | | | | | |
| 99 | .64 | | | | | | |

The results in the first three columns are shown graphically in figure 1. In the results of the second and third lines of the second column an extreme variation was obtained (2.81 and 3.99). A second trial of this was made with the results shown.

Where only two types of seeds are present the variation of the one must be the same as that of the other, since the second always equals 100 minus the first. Therefore, the variation in a 10 percent series would be the same, at least theoretically, as in a 90 percent series, etc., and the greatest variation would be found when each is 50 percent. When three types are present the number of possible combinations is increased and the variation of one series need not be the same as either of the others. The greatest variation would be expected when the percentage of each is equal. Accordingly, one lot was made up in this manner and the probable error found to be 3.83,

3.92 and 3.01 respectively for the three sorts. The deviation of each is shown in figure 2.

Two more series were run with this material and will be mentioned later. Several series of germination tests were also made and the probable error calculated in the same manner. In order to eliminate other factors as far as possible, seeds were used which do not offer special difficulties. All tests were made between folds of blotting

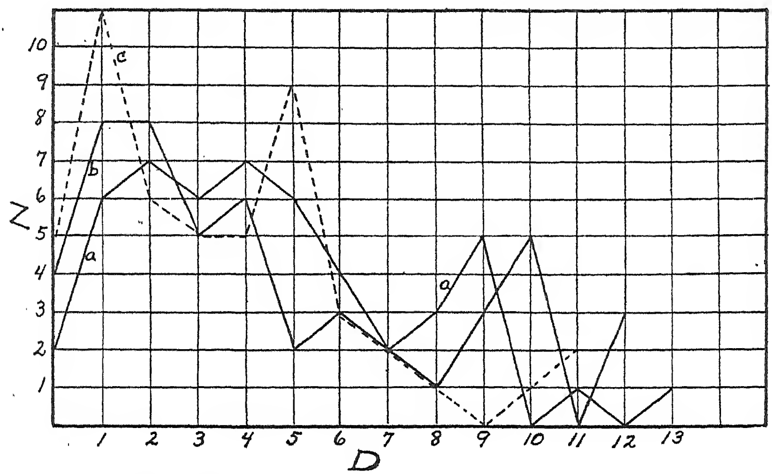


FIG. 2. Graph showing deviation from the mean of each of the components in a mixture of equal parts. *N*, number of deviates in 50 tests; *D*, percentage of deviation in 100 seeds.

paper in the standard germinating chamber at alternating temperature, and each set of 50 was made at the same time by the same person. For sake of comparison, the results of four lots tested by about 20 different laboratories (Stone, 1913), have been calculated and added. These figures are shown in Table 3.

TABLE 3.—*Probable error in germination tests.*

| Kind of seed. | No. of tests. | Percentage of germination. | Probable error in test of 100 seeds. |
|---|---|---|---|
| Alfalfa No. 1 | 50 | 50 (48 hard) | 4.03 |
| Alfalfa (2d trial) | 50 | 50 (48 hard) | 3.35 |
| Alfalfa No. 2 | 50 | 92 (2 hard) | 1.89 |
| Alfalfa No. 3 | 50 | 85 (13.5 hard) | 1.81 |
| Alfalfa No. 4 | 50 | 91 (4 hard) | 2.14 |
| Millet | 50 | 91 | 2.58 |
| Bromus | 50 | 97.5 | 1.18 |
| Alfalfa | 19 | 96 | 1.99 |
| Red clover | 18 | 91 | 2.43 |
| Millet | 18 | 93 | 1.97 |
| Timothy | 18 | 92 | 2.20 |

The preceding work is based upon only 100 seeds for each test. The next question is to what extent the error would be reduced by using a greater number. For this purpose several series of 200 tests each were made in the same manner as before, but each lot of 50 was run at a different time. The results have been calculated for each set of 50 tests, then for each set of 50 obtained by taking the mean of the first and second, third and fourth, etc., and in the same manner for the means of each set of three and four tests, thus giving series based upon 200, 300, and 400 seeds respectively. The results of these are shown in Table 4.

TABLE 4.—*Probable error in using 100, 200, 300 and 400 seeds.*

| Kind of seed. | Percent of germination. | Number of seeds in test. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 100. | | | | 200. | | 300. | 400. |
| | | 1st set. | 2d set. | 3d set. | 4th set. | 1st set. | 2d set. | | |
| Millet | 72.0 | 3.51 | 2.98 | 3.09 | [a] | 2.47 | [a] | 2.25 | |
| Alfalfa | 83.0 (9 hard) | 2.49 | 2.62 | 2.48 | 3.02 | 3.01 | 2.27 | 1.82 | 1.43 |
| Do. | 56.5 (35.5 hard) | 4.10 | 3.63 | 3.32 | 3.51 | 2.79 | 2.53 | 2.72 | 1.91 |
| Flax | 99.0 | .68 | .81 | .61 | .79 | .47 | .52 | .37 | .37 |
| Kafir | [b] 60.0 (32 hard) | 3.53 | 3.78 | 3.24 | 3.26 | 2.72 | 2.26 | 2.10 | 1.82 |

[a] Only 150 tests made.

[b] Not germinated; mixture as in Table 2.

As this method of comparing such data may not be considered permissible, an 80 percent mixture was prepared and a further series of 500 lots of 100 each were counted. The rata thus secured were calculated in four distinct groups and also in combinations as in the former cases, with the following results.

For 100 seeds—2.65 (1st lot of 50);
For 200 seeds—1.78 (2d and 3d lots used as 50 of 200 seeds);
For 300 seeds—1.50 (4th to 6th lots used as 50 of 300 seeds);
For 400 seeds—1.35 (7th to 10th lots used as 50 of 400 seeds).
For each of 10 lots of 50 of 100 seeds each—2.65, 2.55, 3.11, 2.70, 3.21, 2.36, 2.95, 2.41, 2.14, 2.96.
For each of 5 lots of 50 of 200 seeds each—1.69, 1.76, 2.13, 1.77, 1.88.
For each of 3 lots of 50 of 300 seeds each—1.64, 1.50, 1.34.
For each of 2 lots of 50 of 400 seeds each—1.19, 1.35.
For each of 2 lots of 50 of 500 seeds each—1.08, 1.25.
For 1 lot of 1,000 seeds each—0.85.

Figure 3 shows the deviation of 200 lots in the third and fifth series of Table 4 and also for the 500 last mentioned. This figure shows again how little the variation at 50 percent differs from that at 80 percent.

By using less than 100 seeds in each lot the error would be considerably increased. One trial of a 50 percent mixture, using 50 lots of 50 and 25 seeds each, gave probable errors of 4.26 and 6.73 respectively.

Another question arises in this connection. If the results of two tests vary rather widely, does it follow that the mean of the two is farther from the mean of the series than when the variation between

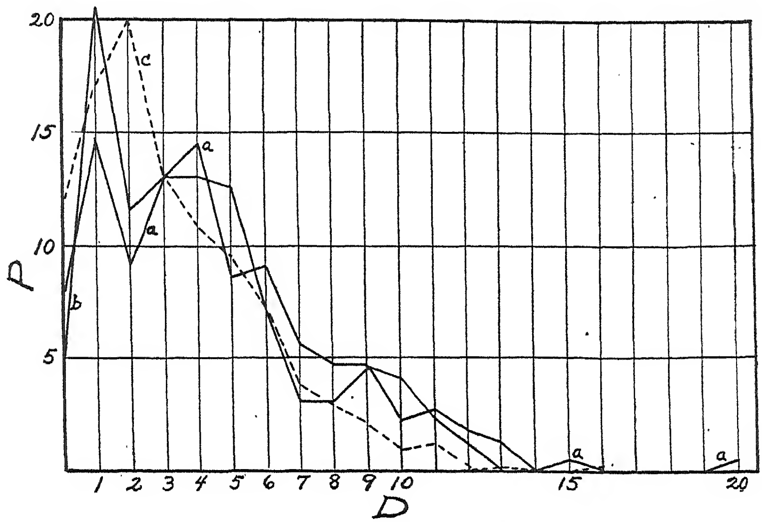


FIG. 3. Deviation from the mean of 200 and 500 lots of 100 seeds each. *P*, percentage of deviates; *D*, percentage of deviation; *a*, alfalfa having 56.5 percent viable and 35.5 percent hard seeds; *b*, Kafir mixture, 60 percent calculated viable and 32 percent hard; *c*, Kafir mixture, 80 percent calculated viable and 20 percent dead.

two tests is less? In other words, is it necessary to make a retest when more than a certain variation occurs between duplicate tests?

To throw some light upon this point the second and fifth series in Table 4 were used. The mean of each successive pair (1st and 2d, 3d and 4th, etc.) was found and the deviation of these means from the mean of the entire series of 200 was found. When these differences are arranged according to the variation of the two tests of each pair the results shown in Table 5 are produced.

The data from the last series of 500 tests were also handled in the same way and in addition the percentage of cases where the mean of the pair exceeded the mean of the entire series by more than the probable error of 200 seeds was found for each group. These data are given in Table 6.

TABLE 5.—*Deviation of duplicate tests.*

| Variation between the members of each pair. | Deviation of mean of each pair from mean of entire series. | | | |
|---|---|---|---|---|
| | Alfalfa series. | | Kafir series. | |
| | Number of deviates. | Average deviation. | Number of deviates. | Average deviation. |
| | | *Percent.* | | *Percent.* |
| 0 | 2 | 2.0 | 5 | 1.6 |
| 1 | 7 | 3.7 | 9 | 2.8 |
| 2 | 11 | 2.8 | 9 | 2.7 |
| 3 | 9 | 2.8 | 13 | 2.3 |
| 4 | 9 | 2.7 | 10 | 3.3 |
| 5 | 10 | 2.7 | 9 | 3.6 |
| 6 | 17 | 3.5 | 14 | 2.4 |
| 7 | 8 | 2.9 | 6 | 4.8 |
| 8 | 2 | 3.0 | 8 | 2.1 |
| 9 | 6 | 4.4 | 4 | 5.4 |
| 10 | 2 | 6.0 | 4 | 4.5 |
| 11 | 6 | 4.5 | 1 | 1.3 |
| 12 | 1 | 2.5 | 1 | 1.2 |
| 13 | 2 | 3.5 | 1 | 3.3 |
| 14 | 5 | 4.2 | 3 | 3.4 |
| 17 | 1 | 4.0 | 1 | 3.3 |
| 18 | 0 | | 1 | .8 |
| 21 | 0 | | 1 | 1.7 |
| 22 | 1 | 1.5 | 0 | |
| 24 | 1 | 7.5 | 0 | |

TABLE 6.—*Variation of duplicates in 500 lots of 100 seeds each, counted from an 80 percent mixture.*

| Difference between duplicates. | Number of cases. | Average deviation. | Number exceeding probable error. | Percentage exceeding probable error. | | |
|---|---|---|---|---|---|---|
| | | | | Individuals. | 3 groups. | 2 groups. |
| *Percent.* | | *Percent.* | | | | |
| 0 | 17 | 2.0 | 11 | 65 | | |
| 1 | 40 | 2.0 | 12 | 30 | | |
| 2 | 29 | 1.8 | 14 | 48 | 45 | |
| 3 | 27 | 2.1 | 10 | 37 | | 48 |
| 4 | 25 | 2.2 | 15 | 60 | | |
| 5 | 22 | 2.4 | 11 | 50 | | |
| 6 | 23 | 2.5 | 15 | 67 | | |
| 7 | 13 | 1.7 | 2 | 15 | 52 | |
| 8 | 10 | 1.5 | 5 | 50 | | |
| 9 | 7 | 3.7 | 6 | 86 | | |
| 10 | 12 | 2.0 | 4 | 33 | | 46 |
| 11 | 9 | 3.7 | 6 | 67 | 49 | |
| 12 | 9 | 2.2 | 4 | 44 | | |
| 13 | 4 | 2.5 | 2 | 50 | | |
| 14 | 3 | 1.7 | 2 | 67 | | |

There is at present a ruling adopted by the Official Seed Analysts of North America that retests should be made when the variation in duplicate tests of 100 seeds each exceeds the following:

6 percent for a germination of 90 percent or more;
7 percent for a germination of 80 to 90 percent;
8 percent for a germination of 70 to 80 percent;
9 percent for a germination of 60 to 70 percent;
10 percent for a germination of 50 to 60 percent.

The writer believes that this regulation is of doubtful value in that it is quite possible for the variation to be greater than this without destroying the value of the test; further, that it is likely to cause an unwarranted faith in results which show smaller variations.

From Table 6 it will be observed that slightly over 20 percent of the series would be subject to retest by the above ruling. The fifth column of the table shows the percentage of cases in which the mean of each pair of tests exceeds the mean of the entire series by more than the probable error of a test of 200 seeds. Since by the nature of the probable error it is exceeded by half of the cases, the amounts in this column should average about 50 percent. If the duplicates which differ more than 7 percent are not to be relied upon, we should expect to see the values in this column higher for variations above 7 percent than for those below. It will be seen from the table that this is not the case; that approximately the same number of high and low values occur in different portions of the column, and that by collecting the results in two or three groups, very little difference is found.

Of the 250 duplicates, 46 showed a difference of over 8 percent between the two members. The average deviation of the means of these 46 from the mean of the entire series was 2.35 percent, while in the other 204 cases it was 2.06 percent. Further, in only 24 of the 46 was this deviation greater than 2 percent (probable error in test of 200 seeds is 1.87 percent). This seems to show plainly that in this case wide variations between duplicate lots did not appreciably reduce the accuracy of the result.

In Table 5, 9 of the 100 duplicates of the kafir series showed a difference of over 10 percent between the mean of the two tests and the mean of the entire series. The average deviation of the means of these 9 from the mean of the entire series was 2.44 percent; that of the other 91, 2.97 percent. Only in 4 of the 9 did this deviation exceed the probable error of 2.2 percent.

In the alfalfa series given in the same table, 17 of 100 exceeded the limit of 10 percent, the average deviation being 4.15 percent, and 12 of the 17 exceeding the probable error. The average deviation of the other 83 was 3.44 percent.

The results of this alfalfa series seem to oppose the writer's contention, yet the data are few and the kafir series tends the other way to about an equal extent. It is to be noted further than among duplicates showing only slight variations the means may differ widely from the mean of the series. For instance, in the alfalfa series just mentioned there is one case among the duplicates which vary only 1 percent in which the mean of the two differs from the mean of the series by 9 percent; among those differing by 2 percent, there are two showing 6.5 percent and one 5.5 percent, etc.

This is a point which the writer wishes to emphasize especially. If duplicates vary only slightly, it is still uncertain that their mean is accurate to a similar degree. If the conditions for the test are unsuitable this will be even more the case, for if one test fails to germinate properly the chances are that the duplicate will do the same.

### Variations in Purity Tests.

A large number of factors are concerned in the variations in sampling for purity tests, since each of the three chief components of the sample (foreign seed, inert matter, and pure seed) may have a variable number of components. The size and number of the various foreign seeds will play an important part. Thus it may be difficult to find a value of accuracy which shall serve for a large range of cases.

In the following experiments the general plan was the same as in the preceding, viz., 50 tests of each lot made by the same person, the seed used being such that unusual variations would not be encountered. In taking the standard samples for analysis the seed mixer and sampler[4] was used, but the last separation was corrected to the standard weight by dipping out with a spoon or adding in the same manner from the other portion of the separation. The entire lot was not separated each time, enough for several tests being set aside toward the end of the process, this finished, and a similar amount set aside from another separation of the bulk. The bromegrass, although a fairly clean lot, would not run through the mixer, and was poured into a pan, portions being taken from different parts for each lot tested. The results are shown in Table 7.

The large error in foreign seed of the bromegrass is due to occasional seeds of barley and wild oats. Such an occurrence is common in the homegrown bromegrass seed examined by us. Similar condi-

[4] Rules and apparatus for seed testing. U. S. Dept. Agr., Office of Experiment Stations Circ. 34, rev. ed., p. 12. 1904.

TABLE 7.—*Probable error of purity tests as determined with the seeds of several crops.*

| Kind of seed. | Number of tests. | Quantity used. | Pure seed. | Foreign seed. | Inert matter. |
|---|---|---|---|---|---|
| | | *Grams.* | *Percent.* | *Percent.* | *Percent.* |
| Flax No. 1....... | 50 | 10 | 97.88 ± .15 | 0.63 ± .06 | 1.49 ± .13 |
| Flax No. 2...... | 50 | 10 | 97.18 ± .17 | 1.17 ± .13 | 1.65 ± .13 |
| Alfalfa......... | 50 | 5 | 98.00 ± .17 | 1.56 ± .16 | .44 ± .07 |
| Bromegrass..... | 50 | 3 | 89.40 ± 1.00 | .28 ± .32 | 10.18 ± .87 |

tions may be met elsewhere, and in ordinary work the result should be corrected from the examination of a larger quantity for such impurities, if it is apparent that the result would be materially changed thereby.

In all but the last of the above series the percentages were calculated to the second decimal. To show further the value of this, the probable error was calculated for the first two a second time, using only one decimal, with the results shown in Table 8.

TABLE 8.—*Value of second decimal in calculating probable error of purity tests.*

| Test. | Percentage. | Probable error. | |
|---|---|---|---|
| | | Using two decimals. | Using one decimal. |
| Flax No. 1. | | *Percent.* | *Percent.* |
| Foreign seed............... | 0.63 | 0.062 | 0.068 |
| Inert matter............... | 1.50 | .129 | .147 |
| Pure seed.................. | 97.88 | .155 | .157 |
| Flax No. 2.................... | | | |
| Foreign seed............... | 1.17 | .132 | .119 |
| Inert matter............... | 1.65 | .133 | .143 |
| Pure seed.................. | 97.18 | .171 | .172 |

The variation in number of foreign seeds of a given species from the tests reported in Table 7 is shown in Table 9.

TABLE 9.—*Variation in number of foreign seeds in purity tests.*

| Seed examined and foreign seed contained therein. | Average number. | Probable error. |
|---|---|---|
| Flax No. 1: | | |
| *Chætochloa viridis* .................. | 29.3 | 3.8 |
| *Chætochloa glauca* .................. | 9.4 | 1.6 |
| *Echinochloa crusgalli* ................ | 1.2 | .7 |
| *Chenopodium pratericola* ............ | .7 | .5 |
| Flax No. 2: | | |
| *Chætochloa viridis* .................. | 14.0 | 2.1 |
| *Chætochloa glauca* .................. | 36.6 | 4.4 |
| Alfalfa: | | |
| *Chenopodium album* ................. | 88.5 | 7.4 |
| *Ambrosia artemisiæfolia* ............. | 1.2 | .8 |
| *Helianthus* sp. ...................... | 1.7 | 1.0 |

| Seed examined and foreign seed contained therein. | Average number. | Probable error. |
|---|---|---|
| Bromegrass: | | |
| *Agropyron tenerum* ................ | 1.4 | .8 |
| *Lappula lappula* .................... | .3 | .4 |
| *Polygonum convolvulus* ............ | .4 | .4 |

One attempt was made to ascertain the variation due to personal selection. The last lot in the first flax series was thrown back together and reworked three times by three analysts, the weighing of each separation being made by one of the other analysts in order to avoid unconscious selection in the next test. The results are presented in Table 10.

TABLE 10.—*Variation in separation of the same sample by different analysts.*

| Analyst. | Foreign seed. | | | Inert matter. | | |
|---|---|---|---|---|---|---|
| | Test No. 1. | Test No. 2. | Test No. 3. | Test No. 1. | Test No. 2. | Test No. 3. |
| No. 1............... | .71 | .70 | .71 | 1.34 | 1.12 | 1.33 |
| No. 2............... | .72 | .71 | .73 | 1.25 | 1.20 | 1.47 |
| No. 3............... | .72 | .72 | .72 | 1.14 | 1.20 | 1.46 |

As the foreign seeds were identical in each case the difference in those columns must be due to inaccuracy in weighing. The balance used was an inexpensive one, but the variation is not of significant value. In case of the inert matter one factor is the distinction between various conditions of broken seeds, these comprising most of the quantity. Further tests of this sort are desirable, but they are difficult to control properly.

## CONCLUSIONS AND RECOMMENDATIONS.

1. The probable error of a single germination test of 100 to 400 seeds varies according to percentage of germination as shown in Table 11.

TABLE 11.—*Approximate probable error for germination tests.*

| Number of seeds used. | Percentage of germination. | | | | |
|---|---|---|---|---|---|
| | 99. | 97. | 95. | 90. | 80 to 50. |
| 100 | .75 | 1.00 | 1.50 | 2.25 | 2.80 |
| 200 | .50 | [a] .70 | [a] 1.00 | [a] 1.50 | 2.00 |
| 300 | .40 | [a] .55 | [a] .80 | [a] 1.20 | 1.75 |
| 400 | .35 | [a] .50 | [a] .70 | [a] 1.05 | 1.50 |

[a] Estimated from the value next above by reducing it in proportion to the results in the first column.

The above figures are increased about one-fifth in the lower percentages of germination for legumes containing the so-called "hard" seeds. This is for work in which the sources of variation are reduced as far as it is possible to do. No attempt is made in this paper to determine the range of variation where factors other than that of mathematical probability enter to any extent. These values may also be used for other experiments involving similar conditions, e. g., counting 500 seeds to determine percentage of mixture of two kinds.

2. For samples not containing mixtures of materials which tend to separate readily (such as sand, fine trash, or coarse material), only a small amount of mixing of samples seems necessary. Samples which do contain such mixtures should receive, when practical, a supplementary test of larger quantity to show the approximate quantity of such materials. For example, these may be separated first by a sieve, and the percentage added to that obtained by a regular test from the remaining quantity.

3. For purity tests the accuracy depends upon many factors. The quantities used should receive a careful investigation in order to determine whether those in current use could be changed to advantage. The use of the second decimal place is of no value in most work. If such accuracy is desired, the test should be based upon a sample of sufficient size.

An instance of such change may be cited in some work carried on at this laboratory in connection with the Improved Seed-Growers' contest. The following schedule was adopted and the second decimal used. For cereals a measured quantity (about 8 ounces for wheat) was used unless the seed was obviously impure, and then the regular quantity (30 gr.) was taken. For flax and smaller seeds, three times the regular quantity was taken unless decidedly impure. This is not suggested as a new basis, but merely mentioned as an instance of a sliding scale which has been used to advantage. In this work the number of seeds of certain noxious weeds, such as wild oats, mustard, etc., was calculated from the larger sample. This is quite an important point and should be carried out for any sorts that are considered of special importance.

4. Results of seed tests should be accompanied by an indication of their accuracy. The regular way of expressing this is by writing the probable error after the result, e. g., $95 \pm 1.5$ percent, thus indicating that the result probably lies between 93.5 percent and 96.5 percent. For ordinary reports it would be desirable to have some form by which it would be stated more completely.

While the probable error represents a very definite quantity, so far as the data from which it is derived are concerned, its practical application is somewhat difficult. Using again the figures of the preceding paragraph, the probable error represents only an even chance that the true result lies within 1.5 percent of 95 percent. The chances are as great that it lies beyond this. If the probable error is doubled, there are about four chances in five that it lies within this figure (95 ± 3, i. e., between 92 and 98). Placing this in another form we see that by allowing twice the probable error, our results will still be beyond this in 20 percent of the trials. This is surely the smallest reasonable allowance that can be made. Then for the smallest practical scale of allowance for variation, the figures in Table 11 should be doubled.

5. Table 8 indicates that the second decimal place is not necessary for the calculation of probable error in such tests. This is quite important as the use of the second place involves several times as much labor in calculating.

6. The amount of seed used for tests (and therefore the degree of accuracy obtained) must be regulated by two factors, viz., the degree of accuracy necessary for dependable results and the amount of work which it is possible to handle. From the data presented in Tables 5 and 6 it would seem that for germination tests, 200 seeds in a single test would be advisable for ordinary work, the number being increased when desired. It is very important that the probable error be known so that such adjustments may be made.

7. Duplicate tests appear to be of little value as, so long as only the factor of probability in selection is present, variation between duplicates is not significant; if other factors enter, the chances are probably as great that duplicates which vary but little are unreliable. The necessity of making another test must be governed chiefly by judgment, whether duplicates vary or not, and a test of 200 seeds will often require less time and space than two of 100 each.

### Comparison with the Results of Rodewald.

As the work of Dr. H. Rodewald came to notice after the present paper was practically completed, it seems desirable to add some extracts showing his results. An abstract of the earlier paper which is a practically complete translation has been published ("G. M. C.," 1891). Rodewald states that errors are either accidental or systematic. A similar statement was made in the beginning of the present paper and in very nearly all of the writer's work an attempt was made

to reduce the systematic errors to a minimum or constant quantity, in order to determine the accidental error.

The data in Table 12, given by Rodewald, were determined by mathematical calculation.

TABLE 12.—*Probable error due to accident.* (Rodewald, 1889, p. 110.)

| Percentage of germination. | Percentage of probable error in using | | | | | |
|---|---|---|---|---|---|---|
| | 100 seeds. | 200 seeds. | 300 seeds. | 400 seeds. | 500 seeds. | 900 seeds. |
| 95 | 1.48 | 1.04 | 0.85 | 0.74 | 0.66 | 0.49 |
| 90 | 2.03 | 1.44 | 1.17 | 1.02 | .91 | .68 |
| 80 | 2.71 | 1.92 | 1.56 | 1.36 | 1.21 | .90 |
| 70 | 3.11 | 2.20 | 1.79 | 1.55 | 1.39 | 1.04 |
| 60 | 3.32 | 2.34 | 1.92 | 1.66 | 1.49 | 1.11 |
| 50 | 3.39 | 2.40 | 1.96 | 1.69 | 1.52 | 1.13 |

Comparing these results with column 1 of Table 2 and with Table 11, they are found to be almost identical, except that the former shows approximately equal values for 80 percent to 50 percent when only two factors are considered. Where the third factor is considered the results conform closely to those given above (indicated in figure 1). Rodewald apparently did not distinguish between these two conditions, nor has he given values for percentages lying between 95 and 100. He found these theoretical values to conform closely with the results from actual tests, but for this he used the results of a number of samples showing approximately the same germination instead of making a large number of tests from one sample.

From several experiments in which results of different laboratories were compared, he found that the systematic error held a rather constant relation to the accidental. From this he finds that the total error is about 2.2 times the accidental error (Rodewald, 1904). From this he derives the following table of variation which should not be exceeded in more than 4.3 percent of comparative tests of 200 seeds each by different laboratories:

| | |
|---|---|
| For 95% germination, 6.3%; | For 70% germination, 14.4%; |
| For 90% germination, 9.4%; | For 65% germination, 15.0%; |
| For 85% germination, 11.2%; | For 60% germination, 15.4%; |
| For 80% germination, 12.6%; | For 55% germination, 15.7%; |
| For 75% germination, 13.6%; | For 50% germination, 15.7%. |

For allowable variation between duplicate tests he gives the following, which will still be exceeded in 4.3 percent of the cases (Rodewald, 1889, p. 226):

| Percentage of germination. | Allowable variation in each test. Using 200 seeds. | Using 100 seeds. |
|---|---|---|
| 95 | 4.62 | 6.57 |
| 90 | 6.49 | 9.04 |
| 80 | 7.62 | 13.06 |
| 70 | 9.78 | 13.82 |
| 60 | 10.38 | 14.77 |
| 50 | 10.65 | 15.08 |

The variation allowed here between two tests at 80 percent germination is but slightly less than the extreme variation between duplicates shown in Table 6. The extent to which the results of Table 5 exceed such allowance is slightly greater but still within the 4.3 percent limit of accuracy of the table. This is surely a confirmation of the writer's contention that duplicates varying 10 percent, 15 percent, or even more may still be reliable tests.

For purity tests Rodewald considered that an allowance of 2 percent could be used for clover samples having a purity of 90 percent or more, and 3 percent for those below 90 percent, and that similar values might serve for grasses, if the purity is determined by the weight method (Rodewald, 1904, p. 113). The mean and probable error of tests by 23 stations was 97.992 ± .406 percent for one sample of red clover, and 70.032 ± 1.288 percent for one of orchard grass. The present writer believes that the space between 90 percent and 100 percent should be further divided, and it should also be borne in mind that the amounts used for purity determination in Rodewald's tests were twice as large as those in current use in the United States.

The writer has quoted thus extensively from this work partly for sake of comparison and partly to give some of the results, as the papers themselves may be relatively inaccessible to many other analysts, as they were to me. My thanks are due to Mr. J. P. Helyar of the New Jersey station and to Mr. Edgar Brown of the U. S. Department of Agriculture for calling my attention to them. Portions of the later paper referring to attempts to reduce the systematic error and comparison of weight and count methods have not been discussed, but it may be well to quote a few statements from the summary:

For the clover sorts both weight and count methods are about of equal value. For fine grasses both have large systematic errors. It would seem that the weight method would be the more easily carried out (p. 113).

The physiological causes for the large systematic errors of germination testing are yet unexplained. It appears that the evaporating conditions play an important role (p. 117).

The large errors of seed testing are not to be sought in the less worthy work of the seed control stations. They are grounded in the nature of the case.

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# VEGETATION AS AN INDICATOR OF THE FERTILITY OF SANDY PINE PLAIN SOILS IN NORTHERN WISCONSIN.[1]

T. J. DUNNEWALD.

While making a survey and report on the soils of a proposed Forest Reserve area in northern Wisconsin, it was noticed that the sandy plains soils varied greatly in their ability to produce a second growth of vegetation after the removal of the original pine timber and the many severe fires which succeeded the logging operations.

The most sandy portions where the original timber was sparse or consisted mostly of Norway and Jack pine, with perhaps a few white pines, now bear little or no second growth. Small Jack or Norway pines 6 to 10 feet high appear in clumps and the poplar brush, if any, is also less than 10 feet high, while a thick growth of sweetfern, brakes, blueberries, or coarse bunch grass is the only ground cover, In other places where moisture conditions appeared somewhat better and the soil slightly more loamy, the second growth is often 20 to 40 feet high and consists of poplars, white birch, cherry, alder, and young white pine, with but few Jack or Norway pines. The original timber also had been of a better quality here, being mostly large white and Norway pine, as indicated by the stumps.

In the final correlation of the soils on the basis of their value for agricultural purposes, the most sandy soil was described as being of low value for farming, while the more loamy soil, as indicated by the vegetation and better moisture conditions, was classed as being

[1] Contribution from the Wisconsin State Soil Survey, Madison, Wis. Received for publication April 6, 1917.

of fair value for future farming. Typical samples from widely separated areas of these classes of soil were collected and analyses made to correct or confirm the field interpretation.

Table I gives a summary of the various determinations made on these two groups of soil samples.

TABLE I.—*Chemical and mechanical analyses of sandy pine plain soils bearing good and poor second growth.*

SOILS WITH SPARSE SECOND GROWTH.

| Soil No. | Chemical analyses. | | | | | Mechanical analyses. | | | | | | | Class of soil. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P. | K. | N. | Lime requirement.[a] | Moisture equivalent. | Gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. | |
| | | | | | | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | |
| 919 *A* | 0.052 | 1.24 | 0.096 | 2,000 | 15.3 | 6.85 | 22.44 | 22.20 | 27.08 | 46.90 | 9.61 | 6.92 | Coarse |
| 919 *B* | .035 | 1.36 | .045 | 500 | 7.4 | 9.10 | 18.43 | 21.58 | 37.37 | 5.42 | 4.74 | 3.35 | Medium |
| 882 *A* | .052 | 1.29 | .063 | 2,000 | 14.8 | | | | | | | | do. |
| 882 *B* | .041 | 1.12 | .033 | 2,000 | 9.8 | | | | | | | | do. |
| 873 *A* | .051 | 0.76 | .095 | 2,000 | 15.0 | | | | | | | | do. |
| 873 *B* | .031 | 0.95 | .027 | 500 | 9.3 | | | | | | | | do. |
| 861 *A* | .042 | 1.11 | .057 | 2,000 | 14.9 | | | | | | | | do. |
| 861 *B* | .027 | .87 | .056 | 2,000 | 11.5 | | | | | | | | do. |
| 859 *A* | | | | | 16.7 | | | | | | | | Medium to fine |
| 859 *B* | | | | | 12.0 | | | | | | | | Fine |
| 743 *A* | .042 | 1.19 | .047 | 2,000 | 12.8 | 2.54 | 15.79 | 29.45 | 28.54 | 6.84 | 8.49 | 5.76 | Medium |
| 743 *B* | .029 | 1.01 | .025 | 500 | 6.6 | 4.03 | 14.57 | 30.30 | 31.11 | 9.87 | 6.17 | 4.13 | do. |

SOILS WITH LARGE SECOND GROWTH.

| Soil No. | P. | K. | N. | Lime requirement. | Moisture equivalent. | Gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. | Class of soil. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 863 *A* | .059 | 1.06 | .099 | 2,000 | 19.9 | 1.25 | 4.33 | 8.40 | 46.17 | 21.18 | 12.37 | 6.32 | Fine |
| 863 *B* | .033 | 1.18 | .049 | 2,000 | 13.8 | 2.00 | 4.13 | 9.20 | 51.01 | 21.62 | 7.95 | 4.18 | do. |
| 862 *A* | .041 | 0.97 | .079 | 2,000 | 16.5 | | | | | | | | do. |
| 862 *B* | .032 | 0.97 | .032 | 2,000 | 13.5 | | | | | | | | do. |
| 849 *A* | .047 | 1.21 | .082 | 2,000 | 21.9 | | | | | | | | do. |
| 849 *B* | .037 | 1.17 | .049 | 2,000 | 16.7 | | | | | | | | do. |
| 780 *A* | .058 | 1.12 | .078 | 2,000 | 22.9 | 7.23 | 20.05 | 20.82 | 14.49 | 8.22 | 20.98 | 8.80 | Medium |
| 780 *B* | .039 | 1.31 | .037 | 2,000 | 15.2 | | | | | | | | |
| 785 *A* | .068 | 1.21 | .094 | 5,000 | 18.4 | 0.85 | 11.07 | 19.04 | 27.93 | 27.06 | 11.26 | 3.20 | Medium to fine |
| 785 *B* | .042 | 1.15 | .028 | 5,000 | 12.7 | 0.80 | 9.44 | 18.33 | 28.51 | 32.98 | 7.47 | 2.64 | Medium to fine |
| 741 *A* | .063 | 0.87 | .068 | 2,000 | 16.9 | | | | | | | | Medium to fine |
| 741 *B* | .030 | 1.08 | .026 | 2,000 | 10.6 | | | | | | | | Fine |

[a] Lime requirement in pounds of calcium carbonate necessary to neutralize the surface 8 inches of soil.

A mechanical separation of the particles of different sizes of which the soils are composed was made on several of the samples. The results, as will be seen in Table I, indicate that the soils with small or sparse second growth must be classed as coarse or medium sand,

while those bearing large second growth should be classed as fine sand because they contain larger amounts of the smaller sized soil particles and fewer of those of larger size. The curves in figure 4 show the total average percentages of soil particles of different sizes in the two groups of samples as shown by the mechanical analyses.

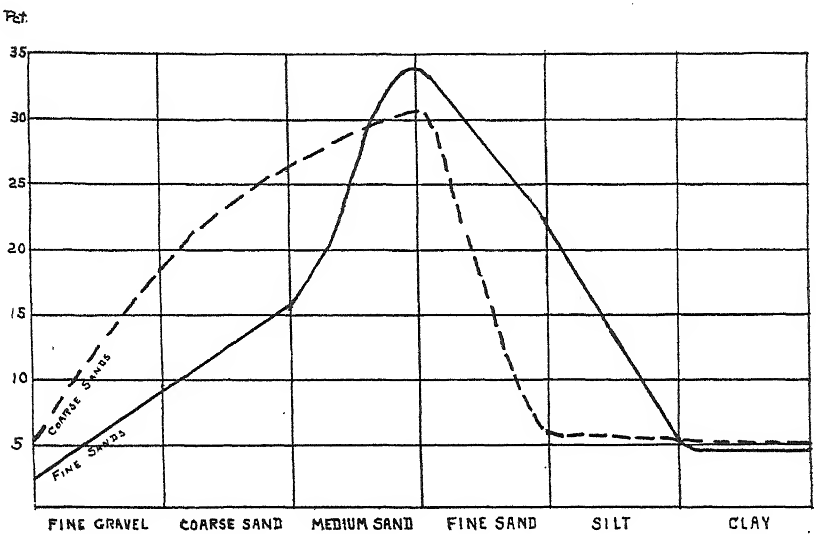


FIG. 4. Graph showing total average percentages of soil particles of different sizes in the two groups of samples (Table 1).

Another arrangement of the percentage in Table 2 indicates the predominance of the finer particles in the soils bearing the best vegetation. It will be seen at a glance that while the content of the finest clay particles is much the same, the silt and especially the finer sands are present in much greater proportion in the soil where the better reproduction is found.

TABLE 2.—*Percentage of silt, clay, and finest sand particles in pine plain soils of northern Wisconsin.*

| Sandy soil, stunted vegetation. | Clay. | Silt. | Fine and very fine sand. | Finer soil, large vegetation. | Clay. | Silt. | Fine and very fine sand. |
|---|---|---|---|---|---|---|---|
| | *Percent.* | *Percent.* | *Percent.* | | *Percent.* | *Percent.* | *Percent.* |
| 919 *A*....... | 6.92 | 9.61 | 31.77 | 863 *A*....... | 6.32 | 12.37 | 67.35 |
| 919 *B*....... | 3.35 | 4.74 | 42.79 | 863 *B*....... | 4.18 | 7.95 | 72.63 |
| 743 *A*....... | 5.76 | 8.49 | 35.38 | 785 *A*....... | 3.20 | 11.26 | 54.99 |
| 743 *B*....... | 4.13 | 6.17 | 40.98 | 785 *B*....... | 2.64 | 7.47 | 61.49 |
| Averages.... | 5.04 | 7.25 | 37.73 | | 4.08 | 9.76 | 64.11 |

Chemical analyses for total phosphorus, nitrogen, potassium, organic matter, and calcium were made on the samples collected. The individual determinations given in Table 1 are averaged for the groups in Table 3.

TABLE 3.—*Percentage of phosphorus, nitrogen, potassium and phosphorus in loamy and fine sands as compared with the coarser sands.*

| Portion of soil. | Coarse sands. | | | Loamy and fine sands. | | |
|---|---|---|---|---|---|---|
| | Phosphorus. | Potassium. | Nitrogen. | Phosphorus. | Potassium. | Nitrogen. |
| | *Percent.* | *Percent.* | *Percent.* | *Percent.* | *Percent.* | *Percent.* |
| Surface............ | 0.048 | 1.12 | 0.071 | 0.055 | 1.05 | 0.081 |
| Subsoil............ | 0.032 | 1.06 | 0.037 | 0.037 | 1.13 | 0.035 |

. The amounts of the plant food elements, phosphorus, potassium, and nitrogen, are low in all these samples as compared with other classes of soil which contain more of the finer soil material, such as clay and silt. The greatest difference between the groups is in the element phosphorus, of which the sandy group have 14 percent less in the surface 8 inches of soil. The element nitrogen is present also in about 14 percent smaller amount in the surface soil of the sandy group than in the loamy soils. Other chemical data not given in the table show that the total calcium is but 0.82 percent in the sandy group and 1.16 percent in the loamy group. Expressed as pounds per acre of soil 8 inches deep the food elements are as shown in Table 4.

TABLE 4.—*Pounds per acre of phosphorus, potassium, and nitrogen in certain Wisconsin soils to a depth of 8 inches.*

| Portion of soil. | Low agricultural value. | | | Fair agricultural value. | | |
|---|---|---|---|---|---|---|
| | Phosphorus. | Potassium. | Nitrogen. | Phosphorus. | Potassium. | Nitrogen. |
| Surface............ | 895 | 20,280 | 1,391 | 1,170 | 26,400 | 3,147 |
| Subsoil............ | 642 | 21,653 | 685 | 855 | 25,530 | 1,151 |

The moisture equivalent determination consists briefly in placing equal bulks of the different soils in perforated cups in a centrifuge machine, after they have absorbed all the water they will hold. They are then subjected to a speed of 2,440 revolutions per minute for 40 minutes and the percentage of moisture remaining after treatment is called the moisture equivalent. The determination is intended to give a comparative figure for the moisture-holding capacity of different soils. The averages of the determinations are shown in Table 5.

TABLE 5.—*Average moisture coefficients of sands and of loamy sand soils in northern Wisconsin.*

| Portion of soil. | Sands. | Fine and loamy sands. |
| --- | --- | --- |
| Surface soil | 14.92 | 19.40 |
| Subsoil | 9.48 | 13.76 |

The group of finer samples, as will be seen, have 27 percent (nearly one-third) greater capacity for holding moisture than have the sands. The difference is about equally divided between the surface and subsoil. The greater capacity of the surface 8 inches of both groups to hold moisture as compared with their respective subsoils may be attributed to the organic matter accumulated in the surface 2 to 3 inches of soil. This material, derived from the partial decay of vegetation, has a very high water-holding capacity. This greater water-holding capacity is an especially important matter in judging of the crop value of sandy soil and the lack of the larger water-holding capacity often means the loss of crops on the more sandy soils during even short periods of drought.

## CONCLUSIONS.

It is concluded that the character and size of the undergrowth of cut-over lands is a safe indicator of the cropping capacity of the soil for agricultural purposes on sandy pine plain lands.

The heavier growth indicates a higher content of plant food, the presence of more fine material in the soil, and especially a greater capacity of the soil to retain moisture and to enable vegetation and future crops to resist periods of drought.

# A MECHANICAL EXPLANATION OF PROGRESSIVE CHANGES IN THE PROPORTIONS OF HARD AND SOFT KERNELS IN WHEAT.[1]

GEO. F. FREEMAN.

Soft wheats of low gluten content are usually found in warm humid or irrigated sections. Many of these varieties when taken to drier, colder climates, produce hard, translucent grains having the horny

[1] Contribution from the University of Arizona, Tucson, Ariz. Read for the writer by Dr. R. H. Forbes at the Second Annual Conference of Agronomic Workers in the Eleven Western States at Pullman, Wash., August 2, 1917. Received for publication August 27, 1917.

texture of wheats characteristic of these conditions. Other varieties produce soft, opaque grains in all situations and there are yet other sorts which produce a greater or less percentage of hard, translucent grains even in warm, humid regions.

With reference to their response to environic conditions, Howard, Leake, and Howard[2] separate wheat varieties into three classes, as follows: (1) Wheats which always remain soft, (2) wheats with a tendency to remain hard, and (3) the majority of varieties in which the consistency varies greatly according to the locality and the conditions under which they are grown. An investigator working upon the relative effects of variety and of climate on the quality of wheat might easily be led to serious errors of conclusion should he chance to include in his tests varieties belonging to only one of these classes. Particularly would this error impend should he work only with class 3. It is not to be understood that the three classes here defined have well marked limits. As a matter of fact they grade insensibly into each other through intermediate types. The three classes, therefore, merely distinguish between groups of hereditary tendencies which are more or less marked in their intensity. Hence, we have a field for almost infinite variety in the nature and sensitivity of the response to environment as expressed in the texture and composition of the wheat grain.

As, however, there are varieties which produce a large percentage of hard grains of high protein content even in warm, irrigated sections and as these are qualities constantly sought by the millers, the question arises as to why the wheats of warm humid or irrigated sections are usually of inferior grade. We have no conclusive evidence that there is any noticeable progressive change in the nature of the climatic reactions of a pure race of wheat when brought to a new environment. In view of the fact that hard wheats of high milling quality are often introduced into these localities with a view to improving the quality of the grain produced, why is it that these better varieties so often are either lost or else soon deteriorate to such an extent that they are no better than the ordinary local sorts? The experiments now to be described had for their object the working out of the mechanism by which these better introductions are lost or else gradually deteriorate.

During several years in which the writer has had under observation the wheats grown on the Arizona Agricultural Experiment Station farm at Yuma, he has noticed that commercial varieties of durum

[2] Howard A., Leake, H. M., and Howard, G. C. Memoirs Dept. Agr. India, v. 5, no. 2. 1913.

wheat have shown little or no tendency to gradually become softer from season to season but that both local and introduced commercial varieties of bread wheats are either entirely soft or else show the usual progressive tendency toward becoming soft.

In the spring of 1912 a large number of heads were selected and in the following fall all were sown in head rows. The pure races thus originated represented five types, as follows: White durum, red durum, poulard, red bread, and white bread wheats. All of these wheats were sown within one week's time, but their ripening periods spread out over about a month's time, extending from the middle of May to the middle of June. Hardness was determined by the percentage of clear, translucent grains. No grain was considerd hard if it had even a spot of starchy, opaque endosperm. The different head rows showed practically every percentage of hardness from 0 to 100. Table 1 gives the average yield in grams per 100 feet of row and the

TABLE 1.—*Correlation of yield and percentage of hard grains in various classes of wheat at Yuma, Ariz., in 1914.*

| Class. | Number of pure races. | Average yield per 100 feet of row. | Average percentage of hard kernels. | Correlation between yield and percentage of hard grains. |
|---|---|---|---|---|
| | | *Grams.* | | *Percent.* |
| White durum | 264 | 2,032 | 77 | + 22 ± 4 |
| Red durum | 37 | 1,481 | 74 | + 26 ± 9 |
| Poulard | 79 | 1,636 | 28 | − 20 ± 7 |
| Red bread | 179 | 1,505 | 53 | − 38 ± 4 |
| White bread | 65 | 3,131 | 23 | − 52 ± 6 |

percentage of hard grains in the five principal groups, together with the correlation between the yield and the percentage of hard grains in each group. In Table 2 the different classes are divided into hard and soft groups according to the percentage of hard kernels each

TABLE 2.—*Number of head rows in each class placed in the hard and the soft groups, with range in percentages, average percentages of hard grains, and yield to the 100 feet of row.*

| Class. | Number of head rows in class. | | Range in percentage of hard grains. | | Average yield per 100 feet of row. | | Natural tendency under Arizona conditions. |
|---|---|---|---|---|---|---|---|
| | Hard. | Soft. | Hard. | Soft. | Hard. | Soft. | |
| | | | *Percent.* | *Percent.* | *Grams.* | *Grams.* | |
| White durum | 95 | 169 | 5–76 | 77–100 | 1,896 | 2,108 | Hard |
| Red durum | 14 | 23 | 18–70 | 74–100 | 1,434 | 1,510 | do. |
| Poulard | 48 | 31 | 0–27 | 31– 92 | 1,686 | 1,560 | Soft. |
| White bread | 79 | 100 | 0–52 | 53–100 | 1,788 | 1,283 | do. |
| Red bread | 51 | 14 | 4–21 | 27–100 | 3,410 | 2,111 | do. |

head row contained. In this table the range in percentage and average percentage of hard kernels in each group are given, with the average yield from 100 feet of row.

Table 1 shows that in the white and red durum varieties there is a plus correlation between yield and hardness, whereas in the poulard and white and red bread wheats the correlation between yield and hardness has the minus sign. In other words, among the durum wheats the harder strains on the average produced most; whereas among the poulards and bread wheats the high yielders were softest. As it has been repeatedly shown (Lyon and Keyser,[3] Howard, Leake, and Howard[4] and Le Clerc and Leavitt[5]) that the soft, opaque yellow berries contain less protein than the hard, horny, translucent grains of the same variety, we may safely assume that these harder grained strains also contained a higher nitrogen or protein content than those with a larger percentage of soft kernels. Now, since practically all commercial varieties of wheat are mixtures of slightly different types and since under the given conditions certain strains produce more than others, when these varieties are sown in a given locality for a number of years, a climatic selection will commence whereby the higher yielding strains will gradually come into ascendency. If now these high yielding strains be the softer ones, the harder strains will be slowly eliminated and we shall find the wheat becoming softer.

One hundred and forty-five head selections were made from a commercial variety of Turkey wheat obtained in Kansas. All of these selections were true to the Turkey type of head, habit of growth, and size and character of kernel. The pure races which they produced, however, differed considerably in their yield and in their resistance to the tendency to become soft under Arizona conditions. Thus the percentage of hard grains in the different strains in 1914 varied from 3 to 100 percent; in 1915, from 29 to 100 percent, and in 1916 from 65 to 100 percent. That these differences were varietal and tended to persist in the same strains from year to year is shown by the correlations between these characters from one year to the next, as follows:

[3] Lyon, T. L., and Keyser, A. Winter wheat. Nebr. Agr. Expt. Sta. Bul. 89. 1905.

[4] Loc. cit.

[5] Le Clerc, J. A., and Leavitt, S. Tri-local experiments on the influence of environment on the physical and chemical characteristics of wheat. U. S. Dept. Agr., Jour. Agr. Research, v. 1, no. 4, p. 276–291. 1914.

Percentage of hard grains in 1914 with
percentage of hard grains in 1915 = 57% ± 4%
Percentage of hard grains in 1915 with
percentage of hard grains in 1916 = 33% ± 5%
Yield in 1914 with yield in 1915 = 55% ± 4%
Yield in 1915 with yield in 1916 = 68% ± 3%

The correlation between yield and percentage of hard grains in these 145 races for the three years were as follows:

1914 = —25% ± 5%
1915 = —17% ± 5%
1916 = —25% ± 5%

The meaning of this may be illustrated by a short study of the results in 1914. The 145 strains may be divided into three approximately equal groups and the average percentage of hard grains and the yield of each group calculated as shown in Table 3. If these strains behaved the same each year (as it has been shown that they do), it is easy to see that the harder races will be practically eliminated in a few years.

TABLE 3.—*Correlation between yield and percentage of hard grains in Turkey wheat in 1914.*

| Number of races. | Average percentage of hard grains. | Average yield in grams per 100 feet of row. | Percentage of total yield. |
|---|---|---|---|
| 54 | 52 | 1,989 | 53 |
| 38 | 59 | 1,387 | 27 |
| 53 | 73 | 744 | 20 |

If, for simplicity of calculation, the races are divided into a harder and a softer group based upon their average percentage of hard grains for the three years and the results from mixed planting calculated on the basis of their respective yields the following figures are obtained.

| Year. | Crop. | Percentage in softer group. | Percentage in harder group. |
|---|---|---|---|
| 0....... | Seed for 1913 | 52 | 48 |
| 1....... | Crop of 1914 and seed for 1915 | 55 | 45 |
| 2....... | Crop of 1915 and seed for 1916 | 59 | 41 |
| 3....... | Crop of 1916 and seed for 1917 | 65 | 35 |

Projecting the results from the average of the past 3 years:

| Year. | Crop. | Percentage in softer group. | Percentage in harder group. |
|---|---|---|---|
| 4....... | Crop of 1917 and seed for 1918 | 70 | 30 |
| 5....... | Crop of 1918 and seed for 1919 | 75 | 25 |
| 6....... | Crop of 1919 and seed for 1920 | 79 | 21 |
| 7....... | Crop of 1920 and seed for 1921 | 83 | 17 |
| 8....... | Crop of 1921 and seed for 1922 | 86 | 14 |
| 9....... | Crop of 1922 and seed for 1923 | 89 | 11 |
| 10....... | Crop of 1923 and seed for 1924 | 91 | 9 |

The above tabulations shows that the hard group is thus practically eliminated at the end of ten years. The gradual softening of an impure race of wheat can thus be explained as a climatic selection without the necessity of assuming any direct or accumulative influence of the climate upon the hereditary substance itself.

In like manner we can understand why the durum wheats remain hard under Arizona conditions, for here there is a plus correlation between yield and percentage of hard kernels (+22 percent). An hereditary distinction between the durum and Turkey wheat is thus brought to light in that the harder strains of Turkey wheat are much reduced in yield whereas in the durum wheats the harder strains are the better yielders. These hereditary distinctions, though not striking in any one season, are sufficient to maintain the hardness of the durum wheat and slowly change the other toward the condition of softness and low nitrogen content usually found among bread wheats which have been grown for a number of years in a warm climate.

To the agriculturist, the economic conclusion is evident. We must discard mixed commercial varieties and grow only pure races of wheat coming originally from a single plant. As it is practically impossible to prevent the mixing of varieties through the custom thrashers on the farm, it is highly important that the seed wheat of the community be maintained in its standard of purity through repeated pedigree selection. This work should be done either by the State or by reputable trained seed breeders and from these the farmer should renew his seed at least every four or five years.

# THE GROWTH OF SHEEP SORREL IN CALCAREOUS AND DOLOMITIC MEDIA.[1]

W. H. MACINTIRE.

The presence of sheep sorrel (*Rumex acetosella*) under field conditions is generally conceded to indicate a distinct need of lime. The thriving growth of this weed on soil known to be poor in lime was responsible for the common belief that the plant grows best in an acid medium. However, it is now known that sorrel will flourish in soil that has been treated with lime; hence the viewpoint, now held most generally, that the plant thrives in acid soils because of lack of competition from those plants which are more sensitive to a low content of the alkali-earthy elements. Recent contributions have been made upon this subject by White[2] and by Pipal.[3]

As confirming the findings of the two articles just mentioned and also as demonstrating the parallel effects of limestone and dolomite, the following brief statement is offered, together with the illustrations in Plate 1. This work was carried out by Dr. J. I. Hardy, now of the Wyoming station, under the direction of the writer. It was a portion of a series of pot-culture experiments which were incorporated in a thesis as a part requirement for the degree of Master of Science during the years 1912–13 and 1913–14.

Twenty 8-inch clay pots were used in the work, ten containing limestone in different percentages and ten containing dolomite in corresponding amounts. The pots were twice treated with asphaltum paint in order practically to eliminate porosity, so that they could be imbedded in the ground and thus insure more uniform and more nearly normal temperature.

Clean river sand and limestone or sand and dolomite constituted the only solid material in each pot. Each of the three materials was sifted through a 1-mm. sieve. Those portions which passed through

[1] Contribution from the University of Tennessee Agricultural Experiment Station, Knoxville, Tenn. Received for publication September 10, 1917.

[2] White, J. W. Concerning the growth and composition of clover and sorrel (*Rumex acetosella*) as influenced by varied amounts of limestone. Ann. Rpt. Pa. Agr. Expt. Sta., 1913–14, p. 46–64. 1914.

[3] Pipal, F. J. Red sorrel and its control. Ind. (Purdue Univ.) Expt. Sta. Bul. 197. 1916.

the 1-mm. sieve but were stopped by the ½-mm. sieve, were taken for the filling of the pots. The media varied from 100 percent limestone or dolomite to none, the difference between the percentage of each stone and 100 percent being represented by sand. The limestone and dolomite percentages were 100, 75, 50, 25, 15, 2.5, 1.0, 0.5, and 0, as shown in Table 1. The densities of the sand and limestones were closely approximate and the aggregate weight and volume of the contents of each pot were practically constant.

The limestone used contained 92 percent $CaCO_3$ and 0.5 percent $MgCO_3$, making a lime-magnesia ratio of 184 to 1, while the dolomite contained approximately 50 percent $CaCO_3$ and 35 percent of $MgCO_3$, or a ratio of 10 to 7. Each pot was supplied with 0.1 percent $P_2O_5$ in the form of precipitated lime phosphate and thoroughly mixed in the dry. No iron was added, since each of the stones carried impurities of this element. A nutrient stock solution containing potassium sulfate, potassium nitrate, and potassium chloride was used as a source of mineral plant food. Aliquots of this solution were diluted and applied at the time of seeding and at subsequent intervals, according to the needs of the plants. In the two pots containing sand without limestone or dolomite there was of course some calcium present as phosphate and probably some traces in the sand itself; hence, 0.2 percent of precipitated $MgCO_3$ was applied to each of these pots in order that no one of the pots should have lime without magnesium.

Sorrel seed was sown in the limestone pots April 2, 1913. The seed was from the ammonium sulfate plats of the Pennsylvania station and was obtained through the courtesy of Prof. C. F. Noll, of that station. A uniform stand was obtained in each of the limestone pots, but on June 13 the plants had grown only to a height of about an eighth of an inch, though they were apparently in normal condition. In order to bring the growing period within the desired limits, the method of obtaining a stand was modified. The seedlings were removed and eight stolons of equal size were planted in each pot. The plants were harvested September 22, 1913, thus giving a growing period of 101 days. The same procedure was carried out with the dolomite pots, the stolons being planted March 31 and harvested July 8, 1914, giving a growing period of 99 days. The yields from the several pots containing both limestones are given in Table 1 and the plants themselves are shown in Plate 1.

It will be noted that the sorrel in the limestone pots was harvested before the forming of seed, while fructification took place in the dolo-

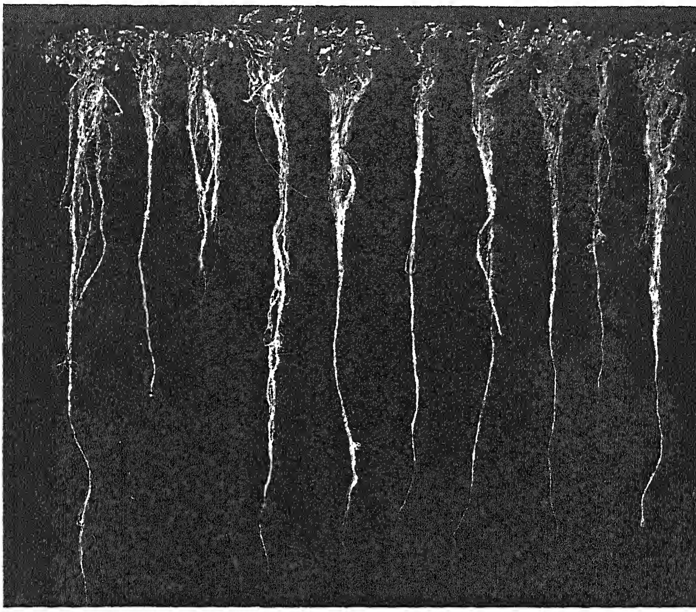

FIG. 1. Growth of sorrel in limestone pots with constant lime-magnesia ratio of 184 to 1. From left to right, the percentage of limestone is 100, 75, 50, 25, 15, 5, 2, 5, 1, 0.5, and 0, the remainder in each case being sand.

FIG. 2. Growth of sorrel in dolomite pots with a constant lime-magnesia ratio of 10 to 7. From left to right, the percentages of dolomite are 100, 75, 50, 25, 15, 5, 2.5, 1, 0.5, and 0, the remainder in each case being sand.

mite pots. However, the limestone series was planted and harvested in 1913, while the dolomite series was handled in 1914. In this respect the two sets of pots are not in strict comparison. It is therefore inadvisable to make deductions as to the influence of the CaO-MgO ratios.

TABLE I.—*Air-dry weight in grams of entire plants of sorrel grown in pots containing varying percentages of limestone and dolomite.*

| Pot No. | Limestone series. | | | Dolomite series. | | |
|---|---|---|---|---|---|---|
| | Limestone. | Sand. | Weight of plants. | Dolomite. | Sand. | Weight of plants. |
| | *Percent.* | *Percent.* | *Grams.* | *Percent.* | *Percent.* | *Grams.* |
| 1 | 100.0 | 0 | 1.61 | 100.0 | 0 | 3.34 |
| 2 | 75.0 | 25.0 | .42 | 75.0 | 25.0 | 6.54 |
| 3 | 50.0 | 50.0 | 1.06 | 50.0 | 50.0 | 1.20 |
| 4 | 25.0 | 75.0 | 1.91 | 25.0 | 75.0 | 1.51 |
| 5 | 15.0 | 85.0 | .75 | 15.0 | 85.0 | 1.38 |
| 6 | 5.0 | 95.0 | 1.83 | 5.0 | 95.0 | 1.02 |
| 7 | 2.5 | 97.5 | 1.48 | 2.5 | 97.5 | 1.57 |
| 8 | 1.0 | 99.0 | 1.24 | 1.0 | 99.0 | 3 96 |
| 9 | .5 | 99.5 | .51 | .5 | 99.5 | 3.87 |
| 10 | 0 | 100.0 | 1.82 | 0 | 100.0 | 1.60 |
| Total...... | | | 10 81 | | | 24.39 |

The results secured demonstrate that the sorrel has no difficulty in maintaining a good growth in strongly alkaline media when not subjected to the intervening influence of clover or other lime-loving plants.

It would seem that the conditions to which the growing plants were subjected in the limestone and dolomite pots are as severe as could be obtained. On the other hand, it is possible that more of the earthy bases might be offered in solution to the plant roots in the case of a fertile soil containing less of lime and more of organic matter; that is, one not so rich in bases but richer in dissolved $CO_2$. However, this may be in turn offset by the extensive area of contact between roots and limestone the solubility of which is appreciable even in distilled water. As a matter of fact, it was impossible to separate mechanically the roots of the plants from the limestones to an extent which would permit the chemical analysis of the plants as a whole. The heavy root development shown in Plate 1 demonstrates very forcibly that an abundance of the earthy alkali carbonates is in no way inhibitory to the subsurface development of *Rumex acetosella.*

# VARIATIONS IN THE DEVELOPMENT OF SECONDARY ROOTLETS IN CEREALS.[1]

E. H. Walworth and L. H. Smith.

In an article appearing in a previous number of this Journal,[2] it was shown that the number of temporary rootlets in cereals, instead of being constant within a given variety, is variable. For example, the author points out that instead of there being a whorl of three temporary rootlets in wheat, according to the usual description given in the literature, the number may be more or less than three and as many as five were noted in some instances. This inconstancy was likewise found to hold true with corn.

Inasmuch as the present writers had an investigation along this line already under way when the above mentioned article appeared and have obtained additional data on this subject, the following observations are presented with the thought that some further information along this line may be of interest. The results are reported of experiments with certain varieties of small grains, including oats, wheat, and barley, with respect to the variations existing in the number of secondary rootlets.

The term "secondary rootlet" is here applied to the temporary roots of the seedling other than the radicle and hence the latter is not included in the data presented. The method followed was to take representative samples consisting of 100 or more kernels from each lot and sow them in pure quartz sand in the greenhouse. The counts were made when the plumules had attained the length of from 1 to 2 inches. The results are set forth in Tables 1 and 2. Table 1 includes a list of some miscellaneous varieties, while Table 2 is made up of several selected strains of wheat and of oats.

In general our observations confirm those of Wiggans, referred to above, in that the number of secondary rootlets is by no means constant for a given variety, but varies among the individuals so that

[1] Contribution from the Plant Breeding Division of the Department of Agronomy, University of Illinois, Urbana, Ill. Received for publication October 13, 1917.

[2] Wiggans, Roy G. The number of temporary roots in cereals. *In* Jour. Amer. Soc. Agron., v. 8, no. 1, p. 31–37. 1916.

TABLE I.—*Variability of secondary rootlets in different varieties of the small grains.*

OATS.

| Variety. | Number sown. | Number germinated. | Number of secondary rootlets. 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wisconsin Pedigree No. 1 | 100 | 89 | | 3 | 60 | 25 | 1 | | | | 2.3 |
| White Russian | 100 | 82 | 1 | 4 | 68 | 8 | 1 | | | | 2.0 |
| Mammoth Cluster | 100 | 81 | 1 | 10 | 55 | 12 | 3 | | | | 2.1 |
| Schoenen | 100 | 92 | | 1 | 50 | 38 | 3 | | | | 2.5 |
| Garton's Victor | 200 | 190 | | 6 | 160 | 23 | 1 | | | | 2.1 |
| White Bonanza | 100 | 91 | | 4 | 48 | 38 | 1 | | | | 2.4 |
| Silvermine | 100 | 92 | | 3 | 51 | 37 | 1 | | | | 2.4 |
| Iowa No. 105 | 200 | 176 | | 5 | 55 | 115 | 1 | | | | 2.6 |
| Big Four | 100 | 90 | | 1 | 54 | 35 | | | | | 2.4 |
| Silver Plume | 100 | 77 | | 5 | 58 | 12 | 2 | | | | 2.1 |
| Black Tartarian | 100 | 88 | | 5 | 74 | 8 | 1 | | | | 2.1 |
| American Banner | 200 | 191 | | 4 | 41 | 116 | 29 | 1 | | | 2.9 |
| Victory | 200 | 172 | | 4 | 30 | 115 | 21 | 2 | | | 2.9 |
| Lincoln | 100 | 95 | | 1 | 24 | 56 | 14 | | | | 2.9 |
| Swedish Select | 100 | 97 | | 1 | 33 | 54 | 9 | | | | 2.7 |
| Siberian | 100 | 98 | | 1 | 46 | 41 | 10 | | | | 2.6 |
| Irish Victor | 100 | 91 | | 1 | 40 | 47 | 2 | 1 | | | 2.6 |
| Danish White | 100 | 91 | | 1 | 60 | 28 | 2 | | | | 2.4 |
| Minnesota No. 6 | 100 | 94 | | | 67 | 26 | 1 | | | | 2.3 |
| Great American | 100 | 95 | | 3 | 26 | 65 | 1 | | | | 2.7 |
| Sixty Day | 200 | 192 | | 11 | 121 | 58 | 2 | | | | 2.3 |
| **WHEAT.** | | | | | | | | | | | |
| Red Wave | 200 | 107 | | 1 | 67 | 28 | 10 | 1 | | | 2.5 |
| Beloglina | 200 | 131 | | 7 | 77 | 32 | 15 | | | | 2.4 |
| Turkey Hybrid 509 | 300 | 122 | | | 25 | 31 | 61 | 5 | | | 2.4 |
| Pesterboden | 300 | 220 | | 4 | 126 | 47 | 43 | | | | 2.6 |
| Dawson's Golden Chaff | 400 | 179 | | | 76 | 49 | 33 | 21 | | | 2.9 |
| Turkey | 500 | 419 | | 9 | 347 | 49 | 14 | | | | 2.2 |
| K. B. 2 | 200 | 76 | | 1 | 58 | 11 | 6 | | | | 2.3 |
| Red Hussar | 200 | 129 | | | 95 | 25 | 9 | | | | 2.3 |
| Turkey Hybrid 402 | 200 | 90 | | 2 | 47 | 29 | 12 | | | | 2.6 |
| Red Cross | 500 | 388 | | 9 | 312 | 55 | 12 | | | | 2.2 |
| Durum | 200 | 83 | | | 9 | 13 | 60 | 1 | | | 3.6 |
| **BARLEY.** | | | | | | | | | | | |
| Oderbrucker | 200 | 147 | | | 1 | 16 | 55 | 65 | 10 | | 4.5 |
| Wisconsin Pedigree | 200 | 152 | | | 3 | 14 | 56 | 66 | 12 | 1 | 4.5 |
| Two-rowed | 200 | 119 | | 3 | 8 | 23 | 46 | 31 | 8 | | 4.0 |
| Beardless | 200 | 114 | | | 1 | 15 | 47 | 45 | 5 | 1 | 4.4 |

counts made on a random sample usually give a frequency distribution represented by a fairly normal curve.[3]

In the case of the oats examined, the number of secondary root-

[3] It should be borne in mind that in order to compare our results with those of Wiggans, it is necessary to deduct one from the count in each case to allow for the radicle which was not included in our counts.

Table 2.—*Variability of secondary rootlets in pure lines of small grains.*

OATS—PURE LINES.

| | Number sown. | Number germinated. | Number of secondary rootlets. | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | Mean. |
| Silvermine 6–403 | 100 | 99 | | 42 | 56 | 1 | 2.6 |
| Silvermine 14–383 | 100 | 92 | 2 | 24 | 64 | 2 | 2.7 |
| Black Gotham 14–173 | 100 | 98 | 1 | 40 | 55 | 2 | 2.6 |
| Black Gotham 13–332 | 100 | 97 | | 23 | 74 | | 2.8 |

WHEAT—INDIVIDUAL PLANTS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Malakoff 1 | 70 | 62 | | 61 | 1 | | 2.0 |
| Malakoff 2 | 100 | 91 | | 90 | 1 | | 2.3 |
| Malakoff 3 | 100 | 98 | 1 | 95 | 2 | | 2.0 |
| Malakoff 4 | 90 | 81 | 1 | 78 | 2 | | 2.0 |
| Turkey Hybrid 509—1 | 60 | 55 | | 37 | 13 | 5 | 2.4 |
| Turkey Hybrid 509—2 | 100 | 99 | | 71 | 20 | 8 | 2.4 |
| Turkey Hybrid 509—3 | 100 | 99 | | 62 | 24 | 13 | 2.6 |
| Turkey Hybrid 509—4 | 100 | 74 | | 32 | 21 | 21 | 2.9 |

lets ranged from 0 to 5. The table also brings out the fact that the different varieties have their characteristic tendencies toward a higher or lower number as shown by the column of averages. This difference is also very well expressed by the number of greatest frequency, or modal number, which in some varieties is 2 while in others it is 3.

Of the eleven varieties of wheat observed nine of them have the modal number at 2 while in the other two varieties 4 is the number of greatest frequency. This is a rather sharp distinction and it would be highly interesting to know whether any significant correlations exist between this rootlet development and other characteristics of the wheat plant. We hope to pursue this matter in subsequent studies.

The barleys exhibit a tendency toward a higher number of secondary rootlets than possessed by either oats or wheat. Here the maximum number rises to 7, while the modal number varied from 3 in some varieties to 4 in others.

It is interesting to note that in the pure-line selections of oats the range of variability is less than that shown in the ordinary varieties, a result which perhaps might have been anticipated. This also holds true for single plants of wheat, although among the latter those of Turkey Hybrid 509 are slightly more variable than the others, which may possibly be accounted for by their hybrid origin.

In connection with this study a somewhat more extensive series of observations was made in maize where an attempt was made to ascer-

tain whether any correlation exists between the development of these secondary seminal rootlets and the yielding capacity. We hope to have the opportunity of presenting some of these results in a future report.


### Summary.

A study of the development of the secondary seminal rootlets in cereals has shown that:

1. The number is not constant, but fluctuates greatly among individuals, variations having been found ranging from 0 to 7.
2. Different varieties of a given cereal show characteristic tendencies in the production of these rootlets.
3. As among the different cereals observed this tendency is greater in barley than in either wheat or oats, as indicated by the varietal averages, modal numbers, and highest extremes.


# THE RELATION OF WEED GROWTH TO NITRIC NITROGEN ACCUMULATION IN THE SOIL[1]

L. E. Call and M. C. Sewell

### Introduction.

The accepted theory of the effect of tillage upon nitrification has been that tillage increased this biochemical action through a favorable influence upon the principal factors governing nitrification. These factors are the incorporation of organic matter, the distribution of bacterial flora, aeration, and moisture. The writers hope to show in this paper that in the past too much emphasis has been placed on tillage as an agent directly contributing to the formation of nitrates through its effect on the above factors and too little emphasis on it as an indirect means of assisting in the accumulation of nitrates by preventing weeds from using them in their growth.

### Review of Literature.

Schlösing and Müntz, Warington, Dehérain (6),[2] and Marquenne (19) were among the earliest investigators to point out the relation

[1] Contribution from the laboratories of the Department of Agronomy (Paper No. 14), Kansas Agricultural Experiment Station, Manhattan, Kans. This paper embodies some of the results obtained in the prosecution of Project No. 18 of the Kansas station. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 12, 1917.

[2] Figures in parentheses refer to "Literature cited," p. 43.

between nitrification and tillage through the incorporation of organic matter in the soil.

The beneficial effect of barnyard manure on crops is common knowledge. That barnyard manure increases nitrification is shown by the recent work of Brown (1), who found that applications of manure up to 16 tons to the acre increased the number of organisms and the ammonifying and nitrifying powers of the soil. He also pointed out the relationship between bacterial activities and crop yields. Temple (18), two years prior to this, published similar results showing an increase of bacterial activities as a result of applications of barnyard manure.

Schlösing (6) advanced the theory that stirring the soil favors the spread of organisms. There are no data today that refute it. We know, however, that the nitrifying bacteria are widely scattered. Müntz and Aubin (6) observed them in many cultivated soils as well as in those of deserts and of high altitudes.

## Aeration.

The value of tillage in aerating soils has been recognized since the time of Liebig (14), who pointed out that the decay of organic matter can only take place with a plentiful supply of oxygen, although putrefaction may occur with limited amounts of oxygen present.

Schreiner and Sullivan (17) explained the important rôle of oxidation in the transformation of mineral and organic matter. They pointed out that whatever decreases oxidation in soils tends also to bring about the conditions which decrease growth, and the factors which favor oxidation are the factors which favor soil productivity.

The fact that oxygen is necessary for nitrification does not necessarily imply that an increase in the supply of oxygen will increase nitrification. Leather (11), as a result of recent investigations of the soil gases, states that "it is certain that the diffusion of gases through soils at a depth of 12 to 15 inches is so efficient as to warrant the conclusion that cultivation of the surface soil is unnecessary for purposes of aeration." His investigations showed that even during the wettest weather the volume of gas falls only to 15 or 20 percent of the total soil volume or about half that which is present during long periods of hot, dry weather.

Russell and Appleyard (16) reported results showing but little variation in the composition of atmospheric and soil air.

King and Whitson (10) have presented investigations on the effect

of increasing aeration on nitrification. They bored holes in the soil and determined nitric nitrogen in the surrounding area. There were no data obtained which indicated that nitrification was increased by this manner of aerating the soil.

In a paper on "The Soil Mulch" Call and Sewell (3) showed that nitrification is as great in uncultivated soil (silt loam) free of weeds as in cultivated soil of the same type.

Gainey and Metzler (8) studied the rate of nitrification in a compacted and an uncompacted soil in the laboratory and found greater nitrification in the compacted soil up to the point where the moisture content reached two thirds saturation.

These results show that while oxygen is essential to nitrification, yet sufficient aeration of the soil takes place under most conditions for optimum nitrification without cultivation.

### Moisture.

Schlösing (6) observed that the nitrates formed in a soil increased with the moisture content until the moisture was sufficient to interfere with the free passage of air.

Patterson and Scott (15) investigated the influence of soil moisture upon nitrification and concluded that—

1. Nitrification is inactive in soil containing three times more moisture than in its natural air dry condition.
2. For both sandy and clayey soils, optimum amounts of water for nitrification lie within the range of 14 to 18 parts per 100 of dry soil.

Coleman (5) found that nitrification in a loam was most active in the presence of 16 percent of water and was much retarded when the amount of water was reduced to 10 percent or increased to 26 percent.

Lill (12), working with the Marshall silt loam soil, found nitrification active between limits of 5 to 35 percent of moisture. He found two maxima, one at 15 percent and one at 30 percent moisture content.

Hutchinson (9) asserts that in the Pusa soil the optimum moisture content for nitrification is 16 percent and that general bacterial action is intense up to 25 per cent.

Gainey (7), working with a silt loam soil, found an increase of nitrification in loose soil with an increase in moisture up to 30 percent.

The writers have shown in a previous paper (3) that the moisture content of uncultivated soil free of weeds equals that of cultivated soils. Thus cultivation could only effect moisture as a factor influencing nitrification through the control of weed growth.

The results of these investigations indicate that the amount of soil moisture has an important bearing on the rate of nitrification and that the moisture condition most favorable for nitrification is about the same as the optimum condition for plant growth. It is also shown that nitrification may be decidedly active with a moisture content much below the optimum. Some discrepancy in the results reported by different investigations is to be expected, as widely different soils were used.

A review of these investigations as a whole indicate that tillage in its effect on the factors influencing nitrification, particularly in its effect on aeration and moisture, will not account for the difference in nitrates found to exist in farm practice in soil cultivated in different ways.

### Experimental Results.

That a marked difference in the nitrate content of soil cultivated in different ways does occur in farm practice is shown by experiments conducted at the Kansas station in which soil has been prepared for wheat in eleven different ways through a period of nine years and in which the moisture and nitrate content of the soil was studied (2). In this experiment wheat was grown continuously and each plot received the same preparation each year. The average yields, the percentage of water available for growth at seeding time, and the amount of nitrates in the soil at seeding time in each plot are given in Table 1.

Table 1.—*Seven-year average yield of wheat, moisture content, and nitrates in parts per million to a depth of 3 feet at the time of fall seeding on 11 plats variously treated.*

| Methods of preparation. | Yield per acre. | Moisture available to plant growth. | Nitrates to a depth of 3 feet. |
|---|---|---|---|
| | *Bushels.* | *Percent.* | *P.p.m.* |
| Disked at seeding | 7.7 | 4.8 | 6.7 |
| Plowed Sept. 15, 3 inches deep | 13.5 | 5.6 | 9.5 |
| Plowed Sept. 15, 7 inches deep | 14.8 | 6.2 | 7.0 |
| Disked July 15, plowed Sept. 15, 7 inches deep | 19.2 | 6.0 | 17.6 |
| Plowed Aug. 15, 7 inches deep, and worked as needed | 20.7 | 6.8 | 17.4 |
| Plowed Aug. 15, 7 inches deep, not worked until Sept. 15 | 19.1 | 6.6 | 16.6 |
| Disked July 15, plowed Aug. 15, 7 inches deep | 19.4 | 6.2 | 24.2 |
| Plowed July 15, 7 inches deep, and worked as needed | 22.0 | 5.8 | 25.1 |
| Plowed July 15, 3 inches deep | 17.1 | 5.7 | 20.7 |
| Listed July 15, ridges worked down | 18.5 | 6.3 | 23.4 |
| Listed July 15, ridges split Aug. 15 | 18.2 | 5.8 | 21.1 |

The amount of nitrates in the soil at seeding time and the subse-

quent yield of wheat were much higher in all cases for early plowing or early preparation of the ground. The large difference in yield can not be attributed to a difference in moisture because the moisture content for all plots is nearly the same. There can scarcely be a doubt of the relation between the development of nitrates and yield of wheat. The question then arises of how to account for this large increase in nitrification and yield with early preparation if we accept the conclusions previously presented.

Some additional data bearing on this question have been obtained by the writers in a study of the effect of weeds and of different depths of cultivation on moisture and nitrate accumulations in the soil. In this study there were four plots; one was cultivated 3 inches deep, one 6 inches deep, one was uncultivated but the weeds were removed with a hoe or by hand, and one was uncultivated and the weeds allowed to grow.

As much moisture was found in the plots that were kept free of weeds but not cultivated, taking a 4-year average, as in the plots cultivated 3 or 6 inches deep (3). The nitrates expressed as pounds per acre 3 feet are shown in Table 2. These data represent the average of samples taken monthly from April to October each year.

TABLE 2.—*Annual and average development of nitrates in plots variously treated, expressed in pounds of $NO_3$ per acre in the upper 3 feet of soil, in the four years from 1914 to 1917, inclusive.*

| Treatment. | 1914. | 1915. | 1916. | 1917. | Average. | |
|---|---|---|---|---|---|---|
| | | | | | 1914–16. | 1914–17. |
| Weeds . . . . . . . . . . . . . | 124.3 | 42.1 | 78.5 | 75.0 | 81.6 | 79.9 |
| 3-inch mulch. . . . . . . . | 497.8 | 495.9 | 246.3 | 225.3 | 413.3 | 366.4 |
| 6-inch mulch. . . . . . . . | 550.1 | 325.2 | 567.8 | No data | 481.0 | |
| Bare surface . . . . . . . . | 712.7 | 643.0 | 313.3 | 228.9 | 556.3 | 474.5 |

It is shown that more nitrates were developed in the uncultivated soil kept free of weeds than in the soil cultivated either 3 or 6 inches deep. It is also shown that there is much less nitrate in the soil which produced a growth of weeds than in the soil which did not produce weeds. It is evident that weed growth and not lack of cultivation is the factor responsible for the low nitrate content of the soil which produced weeds.

In 1916 and 1917 the quantity of nitrogen contained in the weeds grown on the weed plots was determined. The amount of nitrogen in the weeds was calculated as nitrates and added to the nitrates present in the soil. These data are assembled in Table 3 and are

compared with the nitrate content of the cultivated and uncultivated (bare) plots.

TABLE 3.—*Nitrogen in weeds expressed as pounds of $NO_3$ per acre, plus nitrates in the surface 3 feet of soil in October.*

| Year. | $NO_3$ in soil cultivated 3 inches. | $NO_3$ in soil with bare surface. | $NO_3$ in soil producing weeds. | Nitrogen in weed growth as $NO_3$. | Total $NO_3$ developed in weeds and soil. |
|---|---|---|---|---|---|
| 1916..... | 531.5 | 445.7 | 158.3 | 316.0 | 474.3 |
| 1917..... | 372.0 | 361.2 | 36.5 | 322.3 | 358.8 |

The last column of Table 3 gives the total amount of nitric nitrogen which must have been produced in the soil growing weeds, providing the weeds assimilated all the nitrogen used in their growth in the nitrate form.[3] These amounts nearly equal the nitrates present in the cultivated or bare surface soils. The estimate of nitric nitrogen in the weed growth is only for that contained in the tops.

Referring again to the plots prepared in different ways for wheat, it will be seen that similar results have been obtained in regard to the effect of weeds upon nitric nitrogen accumulation in the soil. Determinations of the amount of weed growth and their nitrogen content have been made for the past three years on Plot 1, which is unworked throughout the summer and prepared for wheat by disking each season just before the wheat is sown. The nitrate content of the soil of this plot is compared with that of Plot 9, which is plowed 7 inches deep in July and worked throughout the summer. These data are presented in Table 4.

TABLE 4.—*Nitrogen expressed as nitric nitrogen (pounds of $NO_3$) per acre in weeds and in the surface 3 feet of soil, September determinations.*

| Date. | Nitrates in the soil. | | | Nitrogen expressed as nitric nitrogen in weeds, plot 1. | Nitric nitrogen in plot 1, including that in weeds. | Difference in total nitrates in favor of plot 9. |
|---|---|---|---|---|---|---|
| | Plot 1, disked at seeding. | Plot 9, plowed in July. | Difference in favor of plot 9. | | | |
| 1915 | 18.8 | 127.4 | 108.6 | 150 | 168.8 | −41 4 |
| 1916 | 96.2 | 362.0 | 265.8 | 167 | 263.2 | 98.8 |
| 1917 | 13.4 | 186.5 | 173.1 | 258 | 271.4 | −84.9 |

In this case greater nitrification appears to have taken place in the years 1915 and 1917 upon Plot 1 than upon Plot 9, even though it is only the nitrogen in weed tops that has been considered. As an

[3] It is known that plants can assimilate nitrogen in the form of ammonia and in highly organized compounds, but it is not generally believed that they secure much nitrogen in this way under ordinary conditions.

average for the three years Plot 1 shows a higher accumulation than Plot 9.

Further evidence may be obtained from these plots during the season of 1913, a season which was so dry that weeds failed to grow upon Plot 1. This plot is unworked throughout the summer. Table 5 shows the precipitation for July, August, and September and the nitric nitrogen in the soil September 13 and October 10.

TABLE 5.—*Nitrate (pounds of $NO_3$) per acre to a depth of 3 feet in 1913 on Plot 1 (disked Oct. 1) and on Plot 9 (plowed in July), with the precipitation in July, August, and September.*

| Precipitation in inches. | | | $NO_3$ in soil September 13. | | $NO_3$ in soil October 10. | |
|---|---|---|---|---|---|---|
| July. | August. | September. | Plot 1. | Plot 9. | Plot 1. | Plot 9. |
| 0.07 | 0.37 | 4.89 | 92.9 | 76.5 | 255.5 | 258.7 |

The precipitation during July and August was very light and the rains in September occurred after the determinations were made on the 13th. It will be seen that the accumulations of nitric nitrogen in the two plots when the last determinations were made are practically the same. This would tend to show that the small amounts of nitrates found in the soil of Plot 1 in other seasons (Table 1) are due to the fact that the weeds have used this compound in their growth.

Numerous cultivation experiments with corn show that the principal benefit of tillage is the removal of weeds. Cates and Cox (4) tabulated the results of 125 experiments carried on for six years, 1906–1911, in 28 different States. They concluded that cultivation is not beneficial to the corn plant except in the removal of weeds. Mosier and Gustafson (16), as a result of eight years' work, showed that killing weeds without cultivation produced a gain of 17.1 percent or 6.7 bushels per acre over ordinary cultivation (shallow three times).

At the Kansas station similar data regarding the effect of tillage on corn yields are available for the past three years. These results are shown in Table 6.

TABLE 6.—*Annual and average yields of corn on fall-plowed land, variously cultivated, 1914 to 1916, inclusive.*

| Cultivation treatment. | Yield per acre, bushels. | | | |
|---|---|---|---|---|
| | 1914. | 1915. | 1916. | Average. |
| Ordinary | 13.0 | 65.0 | 43.2 | 40.6 |
| Ordinary and 1 horse cultivator | 13.4 | 62.0 | 43.2 | 39.5 |
| Ordinary and 1 horse cultivator every 10 days. | 11.0 | 58.8 | 43.4 | 37.7 |
| Not cultivated; weeds hoed by hand | 9.2 | 65.0 | 45.2 | 39.8 |

As an average of the three years the uncultivated plots where the weeds were removed produced practically as high yields as the cultivated plots. Apparently there was no advantage from the point of yield in cultivating corn except for the purpose of killing weeds.

Cates and Cox in their report refer to the early work upon the weed factor in cultivation, citing results of Sturtevant at the New York State Station at Geneva in 1886, in Illinois by Morrow and Hunt in 1888 to 1893, in Missouri by Sanborn and Waters in 1889 and 1890, and in South Carolina in 1898 and 1899. Decisive evidence in favor of cultivation was not secured at any of these stations.

If the difference in nitric nitrogen accumulation in cultivated and uncultivated soils is due entirely to the weed growth upon the latter, then the depth of tillage should not affect the development of nitrates. That the depth of cultivation has not greatly affected the accumulation of nitric nitrogen in the soil of the plots prepared in different ways for wheat is shown by the results of the wheat seed bed experiment already discussed in Table 1 and further summarized in Table 7.

TABLE 7.—*Average nitrates per acre in p. p. m. in the surface foot of soils variously treated during the periods of cultivation in the eight years from 1909 to 1916.*

| Treatment. | Nitrates as p.p.m. of $NO_3$ in the surface foot. | | | |
|---|---|---|---|---|
| | July. | Aug. | Sept. | Oct. |
| Disked at seeding | 10.3 | 10.3 | 7.4 | 13.7 |
| Double-disked in July, plowed in August 7 inches deep | 28.9 | 31.9 | 50.6 | 55.6 |
| Double-disked in July, plowed in September 7 inches deep | 24.4 | 34.1 | 26.3 | 42.6 |
| Plowed in August 7 inches deep | 18.3 | 25.9 | 39.5 | 38.3 |
| Plowed in July 7 inches deep | 18.5 | 37.8 | 48.3 | 50.8 |
| Plowed in July 3 inches deep | 18.8 | 32.4 | 36.8 | 44.5 |
| Plowed in September 7 inches deep | 23.3 | 12.7 | 8.0 | 16.0 |
| Plowed in September 3 inches deep | 17.0 | 17.0 | 11.7 | 21.3 |

The soil double disked in July, thus preventing weed growth, and plowed 7 inches deep one month later has an equal or even greater nitrate content than the soil plowed 7 inches deep in July. The soil double disked in July and plowed 7 inches in September contains a much greater nitrate content than the soil plowed 7 inches in September without previous disking. The soil plowed 3 inches in September contains a nitrate content equal to that plowed 7 inches at the same date. This effect of depth of tillage is not entirely substantiated by the data on plowing 7 and 3 inches deep in July, as the

former exceeded the latter in nitrate content. However, the average carbon and nitrogen analyses of Plots 9 and 15 may explain this difference in nitrification. The carbon content of the surface 7 inches of Plot 9 has been 1.74 percent; of Plot 15, 1.53 percent. The nitrogen content of Plot 9 has been 0.148 percent; of Plot 15, 0.131 percent. Plot 9 then contained 14 percent more carbon and 13 percent more nitrogen than Plot 15. It seems possible that this difference in the quantity of nitrates liberated in this case may be due to original differences in the soil upon which the work was done.

## Summary.

It appears from the data presented that in the past too much emphasis may have been placed on tillage as a direct means of conserving moisture and liberating plant food and too little emphasis on it for the purpose of destroying weeds. If moisture is lost from the soil principally through weed growth and if nitrogen and other elements of plant food become available rapidly in unstirred soil, it is a matter of economy to handle the soil so that weeds may be controlled with the minimum of labor.

It should not be understood that tillage is unessential. It will be necessary to cultivate ground to maintain the proper structural conditions of the soil, to dispose of crop residue on the surface of the soil, to incorporate manures and organic matter in the soil, and to place the soil in suitable condition for seed. Further than this, with the possible exception of heavy types of soil, it is doubtful if tillage is essential where the soil is in a receptive condition to absorb rainfall and where there is no weed growth.

Systems of good farming should be practiced which will assist in controlling weeds, such as a rotation of crops, the use of livestock, especially sheep, for grazing purposes, and timely tillage. By the use of such methods cultivation may be reduced without a corresponding reduction in crop yields.

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# ALUMINUM AS A FACTOR INFLUENCING THE EFFECT OF ACID SOILS ON DIFFERENT CROPS.[1]

BURT L. HARTWELL AND F. R. PEMBER.

Attention has been directed by various investigators to the injurious effects arising from the hydrolysis of aluminum salts because of the free acid caused thereby as measured by an increase in the concentration of the hydrogen ions. The entire emphasis has been laid heretofore upon the increase in acidity as the disturbing factor and not upon the aluminum itself.

The Rhode Island station has for a number of years been interested in attempts to ascertain why different kinds of plants varied so remarkably in their response to liming.[2] For example, under the same conditions barley may be increased two to three times by liming and rye receive no benefit whatever. Nevertheless, the authors found that the addition of acid to ordinary nutrient solutions had as depressing an effect upon rye as upon barley seedlings.[3] From this it seemed probable that the toxicity of so-called acid soils was not attributable only to the acid, for in that case the two seedlings should have been affected alike.

Whenever the influence of the various factors which we have studied was the same on the two seedlings we have been disinclined to accept those factors as being very helpful in explaining the varying needs of different crops for lime.

The aqueous extract of an acid soil, like the soil itself, affected the two kinds of seedlings very differently, showing that it contained some ingredient not present in an ordinary nutrient solution.

Sterilization, dialysis, partial distillation, etc., indicated that the substance was crystalloidal in nature. By evaporating the extract,

[1] Contribution No. 240 from the Agricultural Experiment Station of the Rhode Island State College, Kingston, R. I. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Hartwell, Burt L., and Damon, S. C. The comparative effect on different kinds of plants of liming an acid soil. R. I. Agr. Expt. Sta. Bul. 160. 1914.

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igniting, and dissolving the residue in acid, a culture medium was obtained which was much more injurious to barley than to rye.

Aside from the ordinary nutrients the residue was found to contain silicon, aluminum, and chromium; titanium and certain other ingredients which may have been present were not sought. Owing to the presence of considerable aluminum, studies were begun to determine the specific effect of this element by itself and in combination with silicon, chromium, and other substances.

Although the work had to be interrupted frequently, the cumulative impression caused by the results led to a disinclination to accept acidity as the only, or perhaps the main toxic factor influencing the growth of plants on acid soils.[4]

When c.p. aluminum sulfate about equivalent to the amount of aluminum found in the soil extract was used in nutrient solutions the barley seedlings were depressed much more than the rye, but when the same amount of sulfuric acid unaccompanied by the aluminum was present the rye was depressed as much as the barley.

The hydrolysis of the aluminum sulfate was sufficient to give only about one fourth the concentration of hydrogen ions as that resulting from the equivalent amount of free acid. It seems therefore that aluminum must have been the main cause of the depression in the growth of barley and that its effect on rye was much less. In other words, the two seedlings were affected differently by the nutrient solution containing aluminum, the same as they were by the aqueous extract of an acid soil.

If aluminum as such is an important factor to be considered in connection with the deleterious effect of acid soils, any treatment which renders it less active will prove beneficial. It seemed reasonable that a thorough treatment of the soil with a soluble phosphate might accomplish this object. A moist acid soil upon which most kinds of plants were unable to exist was kept intimately mixed for about two weeks with acid phosphate added at the extraordinary rate of 28 tons per acre, after which lettuce was planted. This crop could not exist in the unphosphated soil supplied only with nutrients, but the soil treated with the acid phosphate produced a maximum crop, even more than when lime replaced the phosphate.

It was shown that for a considerable time at least the large amount

[4] Hartwell, Burt L., and Damon, S. C. Loc. cit., p. 416. *Also* Hartwell, Burt L. Twenty-eighth annual report of the Director of the Agricultural Experiment Station. *In* Report of the Board of Managers, Bul. R. I. State College, vol. 11, no. 4, p. 28. Feb., 1916.

of acid phosphate greatly increased the acidity, and yet a crop which usually responds markedly to liming had made its maximum growth on a very acid soil without the addition of any lime. The solubility of the aluminum in dilute acetic and carbonic acids had been markedly reduced by the phosphate, just as it doubtless would be by lime or by a mixture of the two.

Determinations of the amount of what may be called active aluminum may prove to be as desirable as acidity determinations, and the lime requirements of a soil may be due to the need for lime to precipitate toxic aluminum quite as much as to neutralize soil acidity. In fact, the authors found that after sufficient hydrated lime had been added to produce a maximum crop of lettuce a lime requirement equivalent to from 4,000 to 5,000 pounds of calcium oxid per acre, according to a procedure yielding results similar to the Veitch method, still existed at the end of the vegetation experiment, in spite of the fact that nearly all the lime had entered into reaction with the soil. Many instances might be cited for the economic application of acid phosphate apparently in excess of its need for nutrient purposes.

The details of the work upon which are based the ideas here presented will be published in other connections, but it is hoped at this time to interest agronomists in the application of the results to their problems.

# AGRONOMIC AFFAIRS.

## MEMBERSHIP CHANGES.

The membership reported in the November number was 653. Since that time 6 new members have been added and 1 has been reinstated, while 6 have resigned and 1 not previously reported has been dropped for nonpayment of 1916 dues. The membership therefore remains at 653. The names and addresses of the new members and of the reinstated member, the names of those who have resigned or lapsed, and such changes of address as have come to the notice of the Secretary are given below.

### New Members.

Alexander, L. L., Farm Crops Dept., College of Agr., Columbia, Mo.
Freeman, H. A., Central Expt. Farm, Ottawa, Ontario, Canada.
French, W. L., 1221 Laramie St., Manhattan, Kans.
Hagy, F. S., 924 Fremont St., Manhattan, Kans.
Kan, T. T., Box 95, College Station, Texas.
Stadler, L. J., Farm Crops Dept., College of Agr., Columbia, Mo.

### Member Reinstated.

Garren, Geo. M., College of Agriculture, Raleigh, N. C.

MEMBERS RESIGNED.

John B. Abbott,
Elmer D. Ball,
James M. Bell,
Geo. F. Corson,
Martin Nelson,
M. H. Young.

MEMBER LAPSED.

Jens Olsen.

CHANGES OF ADDRESS.

Babcock, F. Ray, Crosby, N. Dak.
Binford, E. E., Stephenville, Texas.
Chapman, James E., Granada, Minn.
Cron, A. B., Box 1214, Amarillo, Texas.
Dougall, Robert, The Davenport, 17 Kellogg Ave., Amherst, Mass.
du Buisson, J. P., University of Stellenbosch, Stellenbosch, South Africa.
Frank, W. L., Bureau of Markets, U. S. Dept. Agr., Washington, D. C.
Hill, W. H., Lab. Inland Rev. Dept., 249 Hastings St., E., Vancouver, B. C.
Macfarlane, Wallace, 55 S Street, Salt Lake City, Utah.
Myer, D. S., Extension Div., Purdue Univ., La Fayette, Ind.
Nevin, L. B., 433 Seventh St., Hollister, Cal.
Packard, Walter E., Extension Div., Agr. College, Berkeley, Cal.
Pendleton, Robert L., Agr. Dept., Ewing Christian College, Allahabad, India.
Shantz, H. L., Chula Vista, Cal.
Stokes, W. E., County Agent, Edgefield, S. C.
Taggart, J. G., School of Agr., Olds, Alta., Canada.
Voorhees, John H., Agr. Lime Bureau, 503 Riggs Bldg., Washington, D. C.
Wheeler, H. J., 111 Grant Avenue, Newton Centre, Mass.
Wyatt, F. A., 216 Agr. Bldg., Urbana, Ill.

## NOTES AND NEWS.

C. H. Bailey has resumed his work in cereal chemistry at the Minnesota station after a year's leave of absence, during which he was in charge of the laboratory of the Minnesota Grain Inspection Department at Minneapolis.

Ross L. Bancroft has been advanced from assistant professor to associate professor of soil fertility at Iowa State College.

T. P. Cooper, for the past several years dean of the North Dakota College of Agriculture and director of the station, has been elected to a similar position in the University of Kentucky and entered on his duties there January 1.

J. E. Chapman has been appointed instructor in soils at the Minnesota college and station.

Walter E. Clark, of the department of political science of the College of the City of New York, has been appointed president of the University of Nevada and has entered on his new duties.

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# CROP CENTERS OF THE UNITED STATES.[1]

ADOLPH E. WALLER.[2]

## THE RELATION OF VEGETATION TO EVAPORATION AND RAINFALL.

The geographic distribution of our important crop plants appears on investigation to be in accord with the well-known centers of natural vegetation. Attention has been called (Transeau, 1905)[3] to the separation and restriction of groups of plants to regions where the combination of factors most suited to the development of the group was localized. Transeau was able to show this by a map of the rainfall evaporation ratios computed from data on evaporation from a free water surface (Russell, 1888) and the known precipitation for the same station. The ratio is an attempt to combine moisture and temperature data as related to plant growth into a single significant figure. His mapped results clearly indicate the desert region, the plains, the prairies and their eastern extension in Illinois, as well as the forest types of the East, namely, the central deciduous, the northeastern evergreen, the southeastern evergreen, and the insular tropical. Had Russell's evaporation data been more complete the ratios for the whole country could have been presented.

As it is, the map (fig. 5) makes an acceptable working basis for outlining the vegetation of the North American continent and re-

[1] Contribution 99 from the Botanical Laboratory of the Ohio State University, Columbus, Ohio. Received for publication August 7, 1917.

[2] The writer acknowledges with much pleasure the advice and assistance given him by Dr. E. N. Transeau during the preparation of this paper, which is a preliminary part of work being carried on under his direction.

[3] References are to "Literature cited," p. 81.

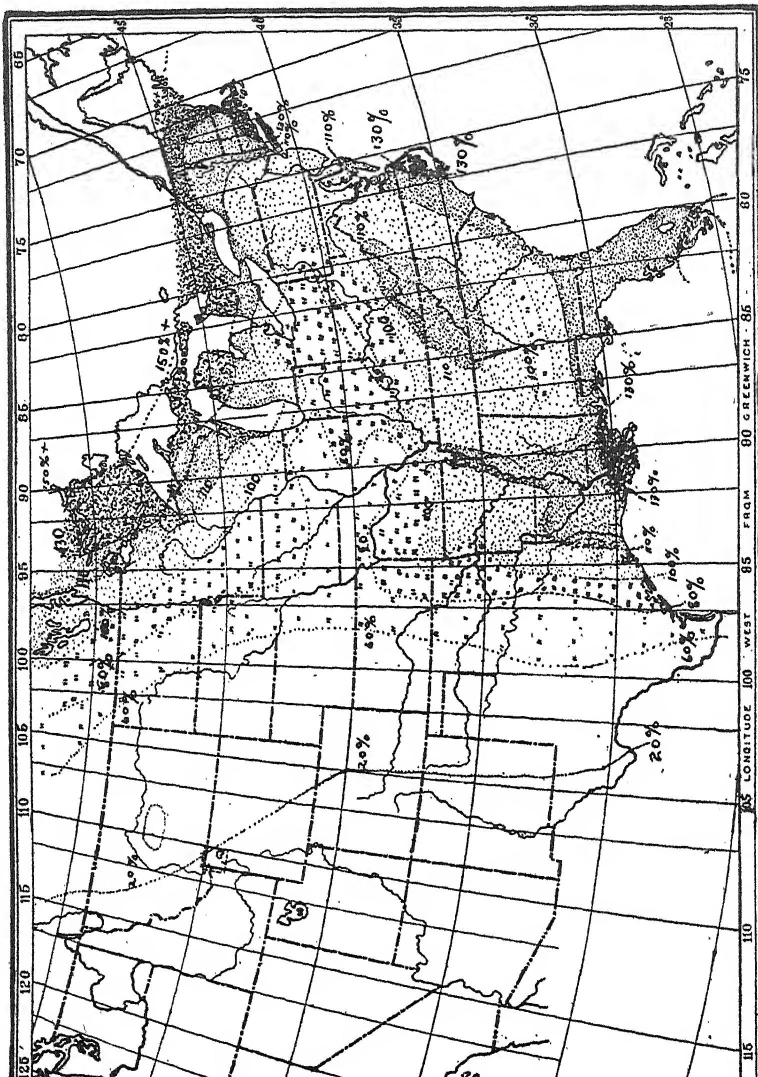



FIG. 5. The ratio of rainfall to evaporation expressed in percentages. Data for the Pacific Coast are not available. The desert lies west of the 20 percent line, the grasslands from the 20 percent to the 60 percent line, the prairies and their eastward extensions between the 60 percent and the 80 percent lines. Where the ratio is greater than 1 there are forests. After Transeau, with slight modification.

mains still the best climatic chart that has been published on forest and prairie distribution. In spite of the discrepancy between rainfall and the amount of water available for plants and between the evaporation and transpiration, the map serves as an effective means for visualizing the distribution of the vegetation.

A number of attempts have been made to correlate plant growth with data gathered by the United States Weather Bureau. The evaporation studies made by this bureau are not, however, of much help to students of plant distribution, either agriculturists or ecologists. Since evaporation and transpiration can be so conveniently used to summarize plant activities, we can go so far as to say that the data of the Weather Bureau are only in the most general way of importance to ecologists.

To improve this situation, Livingston (1915), in a paper read during the Columbus meeting of the American Association for the Advancement of Science, suggested that the rainfall be measured in the usual way, but the evaporation be found by the use of standardized atmometers and the Lehanbauer method be used to find the index of temperature efficiency. By multiplying the rainfall-evaporation ratio by the physiological temperature index, a single figure representing the true climatic summation, namely, the moisture-temperature index, could be obtained. This suggested method also would avoid the inaccuracies of Transeau's chart. However, it has not yet become possible to obtain the results from this suggestion. The figures collected by Russell are still the most complete data available on the depth of evaporation.

In measuring depth of evaporation three factors profoundly affecting plant life are involved:

*a*, The temperature of the evaporating surface;
*b*, The velocity of the wind; and
*c*, The relative humidity.

The rainfall-evaporation ratio, as it combines also the total precipitation with those three, might be expected to agree closely with the actual occurrence of the known vegetational types of the country. This has been found to be the case. The similarities between figure 5 and Sargent's (1884) map of the forests of North America are striking.

A 110-percent rainfall-evaporation ratio, an amount that marks one of the boundaries of the northeastern evergreen forest, means that the evaporation called for is exceeded 1.1 times by the total

annual precipitation. A 20-percent ratio means that the precipitation is only two tenths of the evaporation called for from a free evaporating surface. Only plants with a marked ability to conserve water can exist in the face of such severe conditions for plant growth as is found in regions where the rainfall is so inadequate.

It is interesting to note the geographic significance and particularly the direction of the evaporation lines drawn through stations of the same ratio. In the Great Plains region in the vicinity of the 100th meridian a strong north and south tendency is evidenced. This indicates that in spite of the increase in temperature southward the ratio does not vary with the latitude. There is also an increase in precipitation. The irregularities in the direction of the lines developing farther eastward are due to the proximity of large water areas, e. g., the Great Lakes, the Gulf of Mexico, and the Atlantic, and also to the direction of the winds bearing moisture from these reservoirs of the eastern United States. To a limited extent topography is also a factor. In charts showing the mean monthly and the annual relative humidity, Johnson (1906) displays a distortion in the humidity lines similar to that which appears here in the rainfall-evaporation ratios.

## Climatic Origins.

The antecedents of climatic variation are chiefly differences in the latitude, in the unequal warming of land and water areas, the elevation above sea level, and the direction and intensity of the prevailing winds as controlled by the occurrence and movement of anticyclones and cyclones. The differences in latitude classify those parts of the world which are unlike with respect to the angle at which the sun's rays strike the earth's surface. The amount of heat received and the length of the seasons depends upon the latitude. If this were the only consideration and there were no surface factors to react on the atmosphere, it would be only a simple matter to divide the earth into climatic zones.

The difference in the specific heat of land and water, by which the rate of heat absorption and radiation of land and water areas is determined, is an important factor in establishing climate. This difference serves to divide climates into two principal classes, continental and oceanic. The sea takes up heat and gives it off again only one fourth as fast as the land. Climates that are influenced dominantly by the sea or large bodies of water have moderate temperature changes between night and day and between winter and

summer. The oceanic type of climate is in other words equable. Inland, however, where the land absorbs heat and again radiates it three times faster than water does, the temperature changes between day and night and between winter and summer are relatively rapid. Therefore, a variable or continental climate dominates. Since North America, next to Asia, contains the largest land mass, a vast territory in the United States lying between the Rocky Mountains and the 100th meridian possesses a severe continental climate.

The greater the elevation above sea level the more rigorous the conditions for plant growth because of (*a*) lower temperature in summer and winter, (*b*) a drier atmosphere, accelerating evaporation, and (*c*) greater wind velocity. As compensation for these, there are two conditions favoring plant growth, (*a*) greater sunshine intensity and, much more important, (*b*) greater rain and snowfall on the windward slopes. The heavier precipitation is due to the expansion of air as it is forced upward over the sides and summits of mountains in the paths of prevailing winds. On expanding, the air cools and the moisture it contains is condensed. Thus, the mountain sides receive more abundant downpours of rain than the adjacent lowlands. This effect of elevation is markedly evident in the Pacific Northwest coast region where the annual precipitation is more than 100 inches, the heaviest in the United States. The southeast slopes of the Appalachians also have a somewhat greater annual precipitation than the northwest slopes.

The most noteworthy feature of the mountain ranges in America is their north and south trend across the paths of the prevailing winds. The lines of equal rainfall from the Rocky Mountains eastward to the Great Plains are approximately north and south. In the Southern States east of Texas equal rainfall lines follow the general outlines of the Gulf Coast. In the Middle West and eastward to the Atlantic Ocean they are a complex of the combined effects of the Great Lakes, the Gulf, the Atlantic, and the reprecipitated moisture from the forests of eastern America. This last source of moisture for the prairies will be more fully discussed subsequently. The effect of the Appalachians on the rainfall of the territory lying between them and the source of water is much less apparent and also less direct than the effect of the western mountain systems.

The next factors to be considered are the centers of action produced by the large areas of permanent high and low barometric

pressure. While all the permanent centers of action of the world have some effect on the climate of North America only five of these are shown in the accompanying diagram (fig. 6). For the purposes

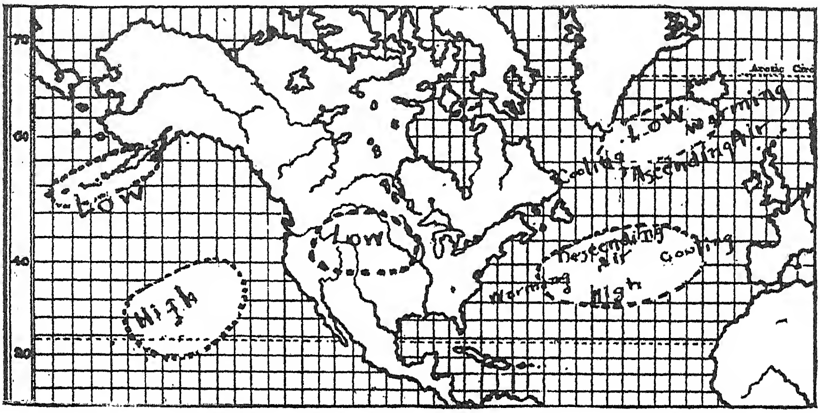



FIG. 6. Diagram of the permanent centers of influence of high and low barometric pressure in the vicinity of North America. The interplay of these and their effect upon the evaporating power of the air and on summer climatic conditions is indicated.

of this paper it is sufficient to consider their operation in summer only, not in winter. Interaction of two kinds is to be considered. The first is the interaction between the anticyclones and the cyclones themselves. In addition, within one given area of action the opposite extremes have reciprocal effects. The eastern side of a high and the western side of a low are regions of ascending, converging, cooling air. This is a region of increasing moisture. The western side of a high and the eastern side of a low are regions of descending, diverging, warming, drying air.

It will be noticed that four of these permanent centers of action are at sea and only one on the continent. While they are said to be permanent this does not mean that they are stable. As a matter of fact they are constantly moving back and forth. If the continental low should shift eastward, or if the western side of the Atlantic high should encroach on the Atlantic coast, the effect on all the area east of the 100th meridian would be the same. Drying, clearing air would descend over the whole region, flowing either from the northwest where the low exists, or from the northeast where the influence of the high is manifested. These two permanent centers of action are the most important in their influence on summer

weather conditions of the greatest part of the United States. If the action of these centers should be just the converse of what has been described, i. e., if the Atlantic high did not encroach westward and the continental low remained in the far north, warm, moist weather conditions would prevail. The effect of these centers on the crops of eastern America is thus plain. If the drying, clearing air conditions lasted a long enough time, a drought and poor crops would result. If these conditions do not exist, then the prevailing winds are from the south and southwest. These, having blown over the reservoirs of the Gulf and the Atlantic, carry in moisture, which is precipitated as the air converges and ascends.

The combined action of differences in latitude, difference in the specific heat of land and water, elevation, and anticyclone and cyclone movements produce in the United States three distinct climates. The first is of the narrow strip of territory from the Pacific Coast to the mountains, an ocean type of climate purely. The second is of the upland plateau from the mountains eastward to the 100th meridian. In the intermountain basins the climatic conditions are locally modified by the presence of water, especially northward, but over by far the greatest part of the region a changeable, continental climate dominates. The third division is from the 100th meridian where a continental climate prevails, to the Atlantic where conditions are influenced dominantly by the ocean. The change is gradual from one type to the other.

On the coastal plains everywhere there are regions of rich, abundant vegetation. This is directly related to the climate, the vegetation being a response to the presence of large amounts of moisture. Climate is also the cause of the Great Plains, with their sparse vegetation and dry, shifting soils. The prairie may be regarded as a transition from the forest conditions of the East to the arid conditions of the central plains. Climate is responsible for the origin of the prairies, but we must look to other factors to explain their persistence. The more abundant moisture of the prairies as compared with the plains has been attributed by Zon (1913), to the forests of the southeastern United States. In his opinion land evaporation is more important than has usually been considered. Moisture does not take a single flight inland from the water areas, but is precipitated and re-evaporated in a series of short flights. The forests, utilizing the water in their own growth, again evaporate the larger portion of it, acting as a temporary deposit bank from which

the moisture may be drawn into the air and redistributed for the use of plants in the path of this moisture-laden atmosphere. His argument has three steps: First, the coincidence of precipitation in eastern United States and the prevailing southerly winds. The cause of the direction of the winds has already been indicated. Second, evaporation from the land constitutes seven-ninths of the total precipitation, while evaporation from the oceans is only two-ninths. Third, a cover of vegetation offers a better evaporating surface than a body of water and a forest evaporates more water than any less dense vegetative cover. There is abundant proof for each of these premises and one is compelled to accept the conclusion that the forests are an important factor in determining the humidity of the prairies.

To say that there is more abundant moisture in the prairies than in the plains is only another way of saying that there is more abundant vegetation. Many plant geographers, including Pound and Clements (1898), C. E. Bessey (1897), Shimek (1911), Gleason (1912), Vestal (1914), and others, indicate or actually state that the forest is migrating across the prairie. If, then, the eastern prairie region is climatically a potential deciduous forest, it appears that the eastern forests in their spread can become moisture bearers and therefore equalizers of climatic conditions farther and farther west. As the lands growing cultivated crops are, next to the forests, the most efficient evaporators, the intensive use of the level lands and the careful forestation of the parts not adapted to cultivation in these eastern States may make large areas of the country far inland from the primary sources of moisture more productive than has hitherto been imagined. The examination of the diminishing prairie areas in Ohio will doubtless throw light on this important problem.

## Climatic and Edaphic Factors.

The natural successions of plant associations in a given region have been recognized for a long time. Cowles (1901) was the first to show that plant successions may be correlated with the physiographic development of a locality. Soil structure, the water-holding capacity of the soil, and the slope of the land are determined by historic and present physiographic changes.

Although we now know that other physical factors independent of the physiography are steps in the plant succession, nevertheless full credit must be given to Cowles for presenting so stimulating a view

as the physiographic one for the first systematized studies on plant successions.

In every stage of their development plants respond to the moisture and temperature changes of the habitat. The nature of the soil has such a far-reaching influence upon plant life that it must be considered second in importance to but one factor, the climate. Those plant growth factors related to the soil have been named by Schimper (1903) the edaphic factors.

Warming (1909), impressed with the fundamental relation between plant growth and available water supply of the habitat, grouped vegetation into three principal classes, hydrophytes, mesophytes, and xerophytes. The water content of soils was made the basis of his work, but when he recently reclassified the three types in order to accommodate them more closely to plant distribution, the new system was too involved to receive general recognition from plant geographers. Schimper made practically the same grouping that Warming made of water-content associations. He also pointed out that the terms forest, grassland, and desert are a subconscious classification of the principal climatic formations and are only another way of expressing the water content of soils.

The effect of the edaphic factors is to modify the climatic influences. The physical and chemical properties of soils tend to diminish or intensify the effect of climatic factors upon plant growth. Thus we might see in regions of moist climate rock faces, cliffs, or sand dunes in which desert conditions would be approached. Xerophytes, those plants physiologically adjusted to drought conditions, would be able to occupy and hold these situations as long as conditions remained little suited for the growth of plants requiring more moisture.

The physical nature of soil structure is more important to plant life than the chemical composition of the soils, due to the relation between soil texture and water content. An illustration of the importance of the structure of the soil is seen in the well-known observation that the plant successions on clay and on sandy soils are the same, but in sand require a much longer time to complete the cycles. It should be stated that although there are observations and records of soil experimentation carried on by careful agriculturists for more than one hundred years, yet much less is known about the soils and their effects upon plant life than has been learned of the climatic factor.

The influence of glaciation in destroying topography of former times and mixing the soils must be pointed out as important to plant

successions and to crops. In the regions of severe glaciation there is a widespread homogeneity and locally extreme heterogeneity of the soil. Plant successions in these regions are quickly identified. Primary successions proceed regularly enough until the climax formation, the maple-beech or the mixed mesophytic forest, is reached. Secondary successions are readily recognized and these also proceed toward the climax. In regions where there was but little leveling and mixing of the soil as the result of glacial action, pioneer stages more difficult to arrange in succession are frequently met. Regions such as those where Fernald (1907) recorded observations on the soil preferences of certain alpine plants come under this distinction. In older, rougher landscapes in the unglaciated southeastern United States investigations conducted by Harper (1914–1917) report the plant formations restricted to areas of different soil classes. The great local diversity of the vegetation led Fernald to classify plants upon a supposed preference for soils of different compositions (based on an analysis of the rock origins only), and Harper to correlate plant distribution with soil types.

In all probability, however, the edaphic factors interfere with the completion of the successional cycles. It is also likely that temporary climaxes have been mistaken for permanent responses. If in the southeast, for example, pines are found on sandy and deciduous trees on clay soils it should not be supposed that there is an inherent preference of pines for sand and oaks for clay. Rather, it is reasonable to believe that the high rate of evaporation and the high rate of humus oxidation known throughout the entire southeast and intensified on sandy soils are factors tending to make the temporary climax of pines persist for a long time. The climax type of vegetation, then, would be composed of evergreens and a large percentage of invaders from the deciduous center, since the latter can make more efficient use of the light and can offer stronger competition for the better soils. Fuller (1914), working in the Lake Michigan sand dunes, has brought out graphically the importance of vegetation in modifying the habitat by the accumulation of humus. He shows by many charts the changes in the transpiration rates which result. Similar studies in the southeastern center, with simultaneous studies on the retardation of humus accumulation due to rapid oxidation, would be interesting and profitable.

The difference in the total annual rainfall and the evaporation in the eastern prairies and the deciduous center is not in itself sufficient to account for the great difference in the vegetational aspects. But

the better distribution of the moisture throughout the year produces the forests of the East, while the intermittent moisture and long drought causes grass to be the dominant type of vegetation of the Middle West. The climatic change is gradual from the 60-percent evaporation line eastward. The continuance of the prairie therefore is largely dependent upon edaphic conditions. Poor soil drainage and the accumulation of muck in the soils seem responsible for the black prairie lands. The prairie peninsula (see fig. 5) lies extended across Illinois to Indiana because of situations unfavorable to drainage and oxidation. Scattered through the glaciated portions of Indiana and Ohio are also small areas of typical prairie. In all of these, until drained and broken, big bluestem (*Andropogon furcatus*), one of the bunch grasses typical of the prairies, can be found.

The plains are more arid than the western part of the prairies and much drier than the eastern part. They lie west of the 60-percent evaporation line. Short grass, a climax association of Bulbilis-Bouteloua, dominates. Just as edaphic prairies are found in the deciduous forest climax, so are edaphic plains in the prairie climax. Gleason (1910) has demonstrated this in the sand deposits of the Illinois River. These deposits date from early post-glacial times when the carrying power of the river was severely overtaxed. Blowouts, common in the sand hills of Nebraska, and the same plant successions proceeding from these wind-eroded, bare areas are reported.

It is interesting to see how climatic and edaphic factors, though independent of one another, can sometimes make the same agricultural practises necessary. An example of this can be noted in the custom of furrow planting in the sand plain near Havana, Ill., an edaphic plains situation, and in western Kansas, the climatic plains. In both of these places grains and seeds are dropped into a deep furrow in order to be as near to the water table as possible. As the plants grow, the hills on either side of the furrow are leveled toward it until by the end of the growing season the plants are standing in hills. It is also significant to know that the cactus, *Opuntia rafinesquii*, is the common weed of the cornfields in these sand areas.

## The Vegetation Centers.

From what has been given it can be seen that the forest centers are understood to mean those regions in which the combined operation of all the climatic and edaphic factors still leaves an environment suited to the most favorable development of the species included in the local vegetation type. For example the white pine, *Pinus*

*strobus*, the black spruce, *Picea mariana*, the hemlock, *Tsuga canadensis*, the balsam fir, *Abies balsamea*, and the paper-bark birch, *Betula papyrifera*, are several trees belonging to the northeastern center. A corresponding list of characteristically dominant trees for the central deciduous center would include the sugar maple, *Acer saccharum*, the beech, *Fagus americana*, the chestnut, *Castanea dentata*, the white oak, *Quercus alba*, and the tulip tree, *Liriodendron tulipifera;* while for the southeastern center the loblolly, *Pinus taeda*, the long-leaf pine, *Pinus palustris*, the sweet bay, *Magnolia glauca*, the bald cypress, *Taxodium distichum*, and the yellow pine, *Pinus echinata*, might be chosen. Whether investigators would agree on these trees as characteristic of the different centers does not so much matter as the point that for each forest center there would be a group of trees of different physiological requirements. In the same way the lists of the dominant vegetation of the plains, the prairies, and the desert would possess marked physiological individuality. Dominance in the sparsely vegetated regions does not carry the sense of having successfully competed with other plants always, but we can speak of dominance because the endemic plants have conquered the environment where so many others failed.

In addition to dominance, Adams (1902 and 1909) has pointed out maximum size, greatest differentiation of type, and widest range of habitat as other criteria of centers of distribution. It is not to be inferred that the center of distribution is necessarily a place from which the species is spreading. Rather it is implied that here the optimum climatic factors are localized and as one leaves a center conditions become less than optimum. Therefore those species which are most completely dependent upon definite conditions are gradually eliminated.

The centers of vegetation are as strongly differentiated by crops as by the native forest trees. Timothy, spring wheat, rye, buckwheat, and potatoes occupy the same region as is marked by the first group of trees; corn, winter wheat, oats, red clover, and beans dominate the central region; while cotton, tobacco, yams, cowpeas, and peanuts center in the southeast. The same criteria applied above for the forest centers hold for the crop centers. The first evidence that we are approaching the center for a given crop is in the number of farms on which it is being grown. The next is that even the rough, hilly, and relatively poor lands produce a fair yield. Then it will be noticed that more varieties of this plant are known and that individuals grow to the greatest size for that variety. As one recedes

from a center the converse is true. The varieties, in some cases species, become fewer and those most rigidly dependant upon definite conditions are eliminated. In even the more tolerant varieties, the individuals begin to dwindle in size. Finally, as with the native plants the centers of dispersal and the centers of distribution are not necessarily the same, so in the crop plants the places where the greatest yields per acre are secured and the regions of greatest production may be widely separated. Indeed, in the case of wheat this is actually true.

The fundamental difference in the occurrence of plants belonging to the natural vegetation and the crop plants lies in cultivation. Man intervenes in behalf of the crop plant which must succeed in spite of the unnatural conditions which it faces. This perfectly obvious truth is repeated here because of the far-reaching effects of plant culture in determining the distribution of the crops when beyond their natural centers. As will be shown, this distribution is quite contrary to the distribution of the natural vegetation.

The indigenous plants beyond their centers can be found in the poorest habitats only where the struggle for existence is equally keen for the invaders from another center and for the members of the center. In Ohio, the white pine from the northern evergreen center and the scrub pine, *Pinus virginiana,* from the southern evergreen center meet on the rock cliffs east of the glacial boundary. Neither one of these invaders can compete with the deciduous forest species that make up the culminating associations in the better habitats. Another example of invaders joining one another in poor habitats is the unique association of the cactus, *Opuntia rafinesquii,* from the southwest and the Jack pine, *Pinus banksiana,* from Canada. The two are found together on the sand dunes near Chicago.

When the crop plants, on the other hand, are to be taken beyond their respective centers they must be given the richest land of the farms. In New York and eastern Pennsylvania when it is desired to grow corn the best fields are employed and these have to be further reinforced and amended by the use of manures. In the Connecticut River valley where tobacco is grown is seen a still more striking instance of man's interposition. Not only are the soil conditions altered but in order to obtain profitable yields the climatic conditions must be altered also by growing the plants under canvas. This shades the plants, lowering the transpiration rate during the day, while at night it prevents too great a loss of heat by radiation. The

climate thus artificially synthesized is more like that which obtains in the center of tobacco production.

The forest centers are plastic groups of plant associations which increase or decrease in size, migrating with climatic changes and movements of the earth's crust. The crop centers are also motile and even less stable than the forest centers. In addition to the physiographic and other physical factors which cause the forest centers to migrate there are economic developments and shiftings in the centers of population which may cause the crop centers to move. The problem becomes still further complicated in the case of the crops grown primarily for human food. Wheat is an example of this. Production is frequently attempted in regions to which the plants are not suited. In time these crops tend to become grouped about their respective centers. The process of change, however, may be a long, slow, and extravagant one.

One often hears that the great cereal crops are moving westward. This is nothing more than the gradual grouping of the centers of production of these crops in the area included between the 40-percent and 100-percent rainfall-evaporation ratio lines. This is where the crops can best be grown. When the United States was first settled by the white man he grew the grain he wanted in regions where it can not be profitably grown now because of competition with other parts of the country where grain production is cheaper than it is along the Atlantic Coast. If the census data from 1849 to date are examined a steady westward migration of the center of wheat production will be plainly seen. It has taken considerably more than half a century to move the center of wheat production about 100 miles north and about 700 miles west or, in other words, from the northeastern evergreen center to the prairie-plains center. When the climatic limits for all varieties of wheat have been reached the western advance, already slowed down, will halt because of limited moisture. It is as yet too early to predict the effect in pulling the wheat center westward of the intermountain edaphic plains regions.

Two economic factors which aided the movement of the wheat center northwest where it is now are, first, the invention in 1870 of a milling device known as the purifier. By its use a handsomer though not a more nutritious flour could be made from spring wheat. Hard spring wheat at once jumped from the least desirable class of wheat for flour to the most desirable class. The movement of wheat towards its center already well begun by the Civil War took a definite step northwest as the result of this invention. The second

factor is the coming of the railroads into the "World's Breadbasket."

But the processes of movement have been too haphazard, uncertain. Unencouraged by the Federal Government and without direction from the experiment stations the movement of crops toward their centers goes on too slowly. In the reorganizations sure to occur within the next few years it is greatly to be desired that the extravagant practices connected with trying to coax a crop from plants not growing in the proper habitats be given attention. Crop ecology, a not yet developed point of view, will have to be made the basis of more intensive studies in crop adaptation and improvement if we are to cope more successfully with the food-supply problems of the coming generations. Seemingly very few of the investigators of crops problems are aware of the importance of the ecological researches that have already been and are being carried on. Many of these have a direct bearing on crops.

As soon as we know more about the possibilities of producing a given crop in any region the difficulties of marketing to the greatest advantage of both the producer and the consumer will be in a position to be solved. Labor and transportation adjustments can be made when the amount of work to be done and the amount of material to be transported can be estimated.

### The Centers of Crop Production.

We are now in a position to examine the geography of the crop centers to discover the relation that they bear to the climatic and edaphic factors of the regions in which they are to be found. Because of the limited space it has been necessary to pick out a few crops only from the many plants cultivated in the United States. It will be noticed in those selected that the choice has been on an economic basis purely, and not because these plants showed remarkably close agreement with any particular conceptions or theories. It would be difficult to substitute readily something else in the place of all the crops given. They therefore have distinct economic value. If, then, there is correlation with the known vegetation centers, it is not because of a prejudice or through skillfully selecting a few plants that would be sure to fit. The selection with respect to the biotic centers has been haphazard. We would be safe in supposing that other crops would show agreement at least as close as those presented.

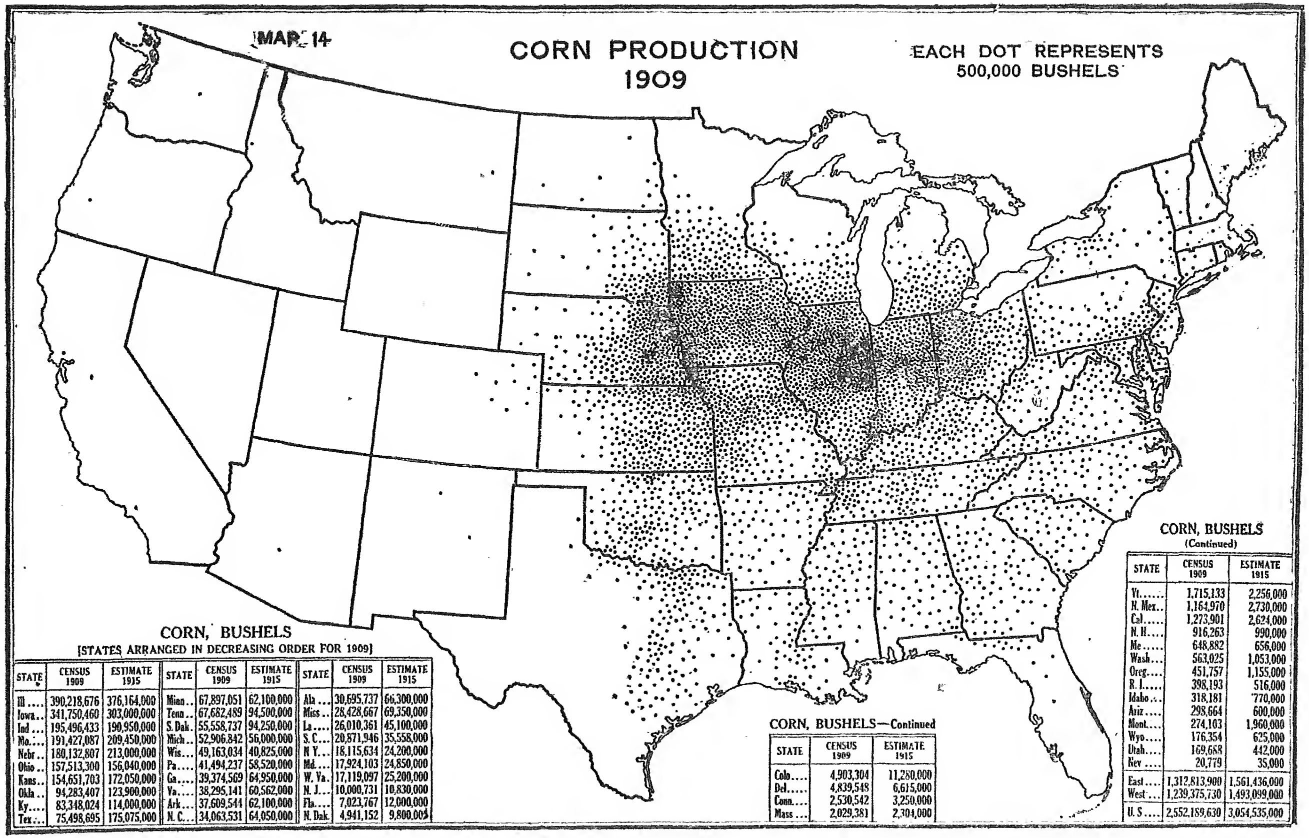
A. THE ATLANTIC COAST TO THE GREAT PLAINS.

The corn and wheat belts agree with the deciduous forest and the prairie centers in the United States. Production of these crops is greatest between the 60-percent evaporation line on the west and the 100-percent and 110-percent lines on the east (see fig. 5).

Three sets of factors are operating in combination to establish this region as the center for the production of our great cereals. These factors may be grouped as climatic, edaphic, and economic. While it is impossible to separate and distinguish these groups of forces in their actual operation, as canceling any one of them would not only destroy the end result but would seriously disturb the equilibrium of the other two, yet there is a strong temptation to analyze the relative weight of these sets of factors.

Without adding any more to the already lengthy discussions of the origin of maize, it is enough to say that it probably had its beginnings in the tropics or the subtropics, showed early a remarkable mutability and adaptability under cultivation so that within perhaps 2,000 years after cultivation began it reached a wide variety of forms and attained a wide geographic distribution. By reason of the hot, almost tropical summers with the relative humidity rather high and the annual rainfall sufficient for the growth of the plant, the entire area from Ohio to central Nebraska on the north and southward to the Gulf of Mexico is suited to corn production. Why, then, when the map (fig. 7) is examined do we find the greatest amount of production in the northern tier of States? This distribution seems odd and could only have been arrived at after a good deal of trouble in finding varieties which could grow under conditions so far from the original environment of the plant. The seven adjacent States from Ohio to Nebraska constitute our "corn belt" and produce 58 percent of the total quantity grown in the United States. Another question which the map provokes is why eastern Illinois is the region of greatest production within the center.

Neither of these questions can be answered simply and directly. On the other hand, to go into all the causes and effects would carry this paper far beyond its original scope, namely, to show where the centers of crop production are located and to suggest as briefly as possible a few of the more obvious reasons which brought them where they are. The climatic factor in Indiana and Ohio is suited to the profitable production of corn, but production centers in Illinois for edaphic reasons. The soil in the eastern portion of this




CORN, BUSHELS

[STATES ARRANGED IN DECREASING ORDER FOR 1909]

| STATE | CENSUS 1909 | ESTIMATE 1915 | STATE | CENSUS 1909 | ESTIMATE 1915 | STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|---|---|---|---|---|---|
| Ill.... | 390,218,676 | 376,164,000 | Minn.. | 67,897,051 | 62,100,000 | Ala... | 30,695,737 | 66,300,000 |
| Iowa.. | 341,750,460 | 303,000,000 | Tenn.. | 67,682,489 | 94,500,000 | Miss.. | 28,428,667 | 69,350,000 |
| Ind... | 195,496,433 | 190,950,000 | S. Dak. | 55,558,737 | 94,250,000 | La.... | 26,010,361 | 45,100,000 |
| Mo.... | 191,427,087 | 209,450,000 | Mich.. | 52,906,842 | 56,000,000 | S. C... | 20,871,946 | 35,558,000 |
| Nebr.. | 180,132,807 | 213,000,000 | Wis... | 49,163,034 | 40,825,000 | N. Y... | 18,115,634 | 24,200,000 |
| Ohio.. | 157,513,300 | 156,040,000 | Pa.... | 41,494,237 | 58,520,000 | Md.... | 17,924,103 | 24,850,000 |
| Kans.. | 154,651,703 | 172,050,000 | Ga.... | 39,374,569 | 64,950,000 | W. Va. | 17,119,097 | 25,200,000 |
| Okla.. | 94,283,407 | 123,900,000 | Va.... | 38,295,141 | 60,562,000 | N. J... | 10,000,731 | 10,830,000 |
| Ky.... | 83,348,024 | 114,000,000 | Ark... | 37,609,544 | 62,100,000 | Fla.... | 7,023,767 | 12,000,000 |
| Tex.... | 75,498,695 | 175,075,000 | N. C... | 34,063,531 | 64,050,000 | N. Dak. | 4,941,152 | 9,800,000 |

CORN, BUSHELS—Continued

| STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|
| Colo.... | 4,903,304 | 11,280,000 |
| Del..... | 4,839,548 | 6,615,000 |
| Conn.... | 2,530,542 | 3,250,000 |
| Mass... | 2,029,381 | 2,304,000 |

CORN, BUSHELS (Continued)

| STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|
| Vt...... | 1,715,133 | 2,256,000 |
| N. Mex.. | 1,164,970 | 2,730,000 |
| Cal..... | 1,273,901 | 2,624,000 |
| N. H.... | 916,263 | 990,000 |
| Me...... | 648,882 | 656,000 |
| Wash.... | 563,025 | 1,053,000 |
| Oreg.... | 451,757 | 1,155,000 |
| R. I..... | 398,193 | 516,000 |
| Idaho... | 318,181 | 770,000 |
| Ariz.... | 298,664 | 600,000 |
| Mont.... | 274,103 | 1,960,000 |
| Wyo.... | 176,354 | 625,000 |
| Utah.... | 169,668 | 442,000 |
| Nev.... | 20,779 | 35,000 |
| East.... | 1,312,813,900 | 1,561,436,000 |
| West.... | 1,239,375,730 | 1,493,099,000 |
| U. S.... | 2,552,189,630 | 3,054,535,000 |

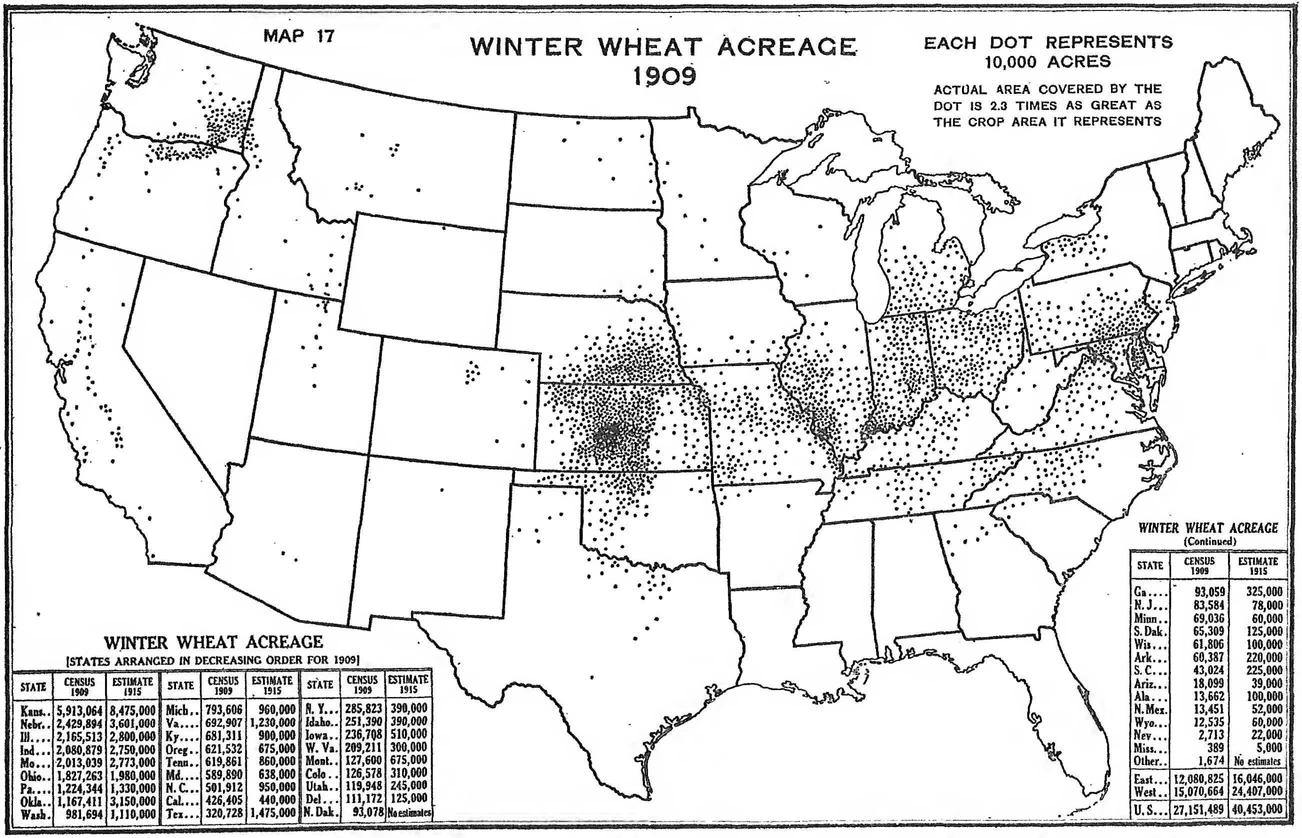
FIG. 7. Map of the United States showing corn production. Most of the level land suited for cultivation lying between the 60 percent and the 100 percent evaporation lines can and should be more intensively farmed for greater corn production. This chart and fig. 5 should be compared. From 1915 Yearbook of the U. S. Dept. of Agriculture. Compiled from unpublished census figures.

State is deeper and richer in humus that can be found elsewhere. Farther southward, where competition with the cotton crop begins, economic reasons prevent a center of corn production from developing. The occurrence of cotton south of Kentucky is a competing factor for both land and labor.

In the United States the average annual yield per acre of wheat for the period 1903–1912 is 14.1 bushels. During that same decade England's acre yield seems to have been 32 bushels, Germany's 30.1, France's 21, and Russia's but 9.7. There is an almost exact inverse proportion between production and yield per acre that offers a fascinating puzzle, for, of the countries named above, Russia and the United States are the greatest wheat producers of the nations. France, Germany, and England follow, not in immediate, consecutive positions but in the order named.

Wheat has come into universal interest and finds its way into every country of the world, which is for it an open market, because it has the capability of adapting itself readily to cultivation under widely different conditions. In the United States wheat production centers on the 60-percent rainfall-evaporation ratio line as can be seen by comparing figures 8 and 9 with figure 5. This means that the center of wheat production lies west of the best corn lands, although on many farms throughout the prairie and deciduous forest climaxes both wheat and corn are usually grown if rotations are practiced. In the matter of growing wheat in regions too dry for corn the United States is not an exception to the rule. The great wheat-producing regions all over the world are level plains with a cool, rather dry climate. It is known that wheat, particularly winter wheat, yields larger crops in the more humid sections, yet in normal times other crops can be grown in the humid parts of the United States with greater profit than wheat. It is competition with these crops that drives wheat to the plains.

A direct effect of climate can be seen in the quality of wheat. Wheat grown in the cooler, drier climates is, in general, harder and darker in color than that grown in the moister, warmer parts of the country. The relative amounts of gluten and starch in the endosperm, determined by the length of the favorable ripening season, are climatic responses. East and south of the 80-percent evaporation line wheat is soft and starchy, with large grains of red, amber, or white color. From the 80-percent limits on the east, westward to where there would be an 80-percent evaporation line extended if there were no prairie peninsula, the wheat is semihard. On and




WINTER WHEAT ACREAGE

[STATES ARRANGED IN DECREASING ORDER FOR 1909]

| STATE | CENSUS 1909 | ESTIMATE 1915 | STATE | CENSUS 1909 | ESTIMATE 1915 | STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|---|---|---|---|---|---|
| Kans.. | 5,913,064 | 8,475,000 | Mich.. | 793,606 | 960,000 | N. Y... | 285,823 | 390,000 |
| Nebr.. | 2,429,894 | 3,601,000 | Va.... | 692,907 | 1,230,000 | Idaho.. | 251,390 | 390,000 |
| Ill.... | 2,165,513 | 2,800,000 | Ky.... | 681,311 | 900,000 | Iowa.. | 236,708 | 510,000 |
| Ind... | 2,080,879 | 2,750,000 | Oreg.. | 621,532 | 675,000 | W. Va. | 209,211 | 300,000 |
| Mo... | 2,013,039 | 2,773,000 | Tenn.. | 619,861 | 860,000 | Mont.. | 127,600 | 675,000 |
| Ohio.. | 1,827,263 | 1,980,000 | Md.... | 589,890 | 638,000 | Colo.. | 126,578 | 310,000 |
| Pa.... | 1,224,344 | 1,330,000 | N. C... | 501,912 | 950,000 | Utah.. | 119,948 | 245,000 |
| Okla.. | 1,167,411 | 3,150,000 | Cal.... | 426,405 | 440,000 | Del... | 111,172 | 125,000 |
| Wash. | 981,694 | 1,110,000 | Tex... | 320,728 | 1,475,000 | N. Dak. | 93,078 | No estimates |

WINTER WHEAT ACREAGE (Continued)

| STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|
| Ga.... | 93,059 | 325,000 |
| N. J... | 83,584 | 78,000 |
| Minn.. | 69,036 | 60,000 |
| S. Dak. | 65,309 | 125,000 |
| Wis... | 61,806 | 100,000 |
| Ark... | 60,387 | 220,000 |
| S. C... | 43,024 | 225,000 |
| Ariz... | 18,099 | 39,000 |
| Ala... | 13,662 | 100,000 |
| N. Mex. | 13,451 | 52,000 |
| Wyo... | 12,535 | 60,000 |
| Nev... | 2,713 | 22,000 |
| Miss... | 389 | 5,000 |
| Other.. | 1,674 | No estimates |
| East... | 12,080,825 | 16,046,000 |
| West.. | 15,070,664 | 24,407,000 |
| U. S... | 27,151,489 | 40,453,000 |

FIG. 8. Map of the United States showing winter wheat acreage. From 1915 Yearbook of the U. S. Dept. of Agriculture. Compiled from unpublished census figures.

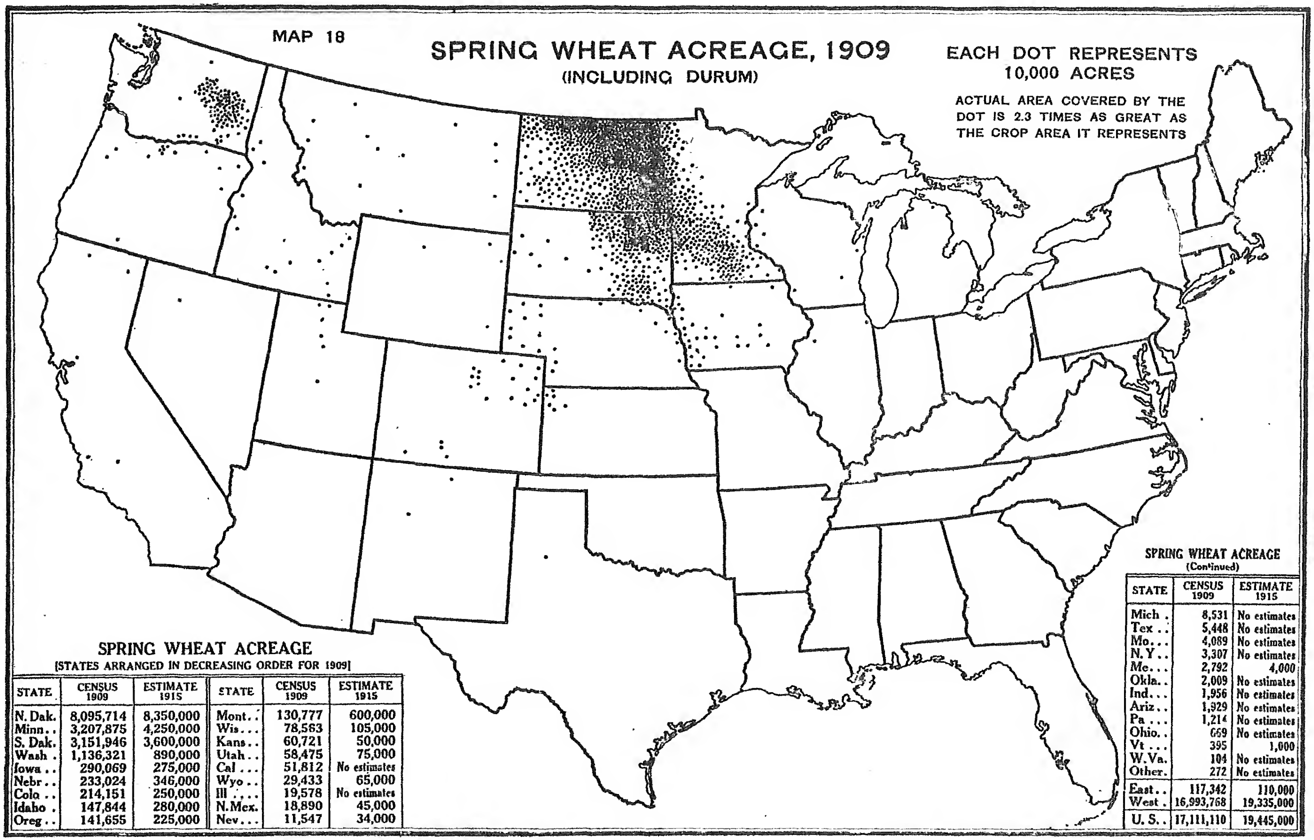
near the 60-percent evaporation line the wheat is darker in color and harder. It makes a flour that is known as "strong." This means that as its gluten percentage is higher, the volume of the loaf is greater than from an equal amount of yeast and flour made from a "weaker" or starchier kind of wheat.

An inspection of the spring wheat chart (fig. 9) shows production to center on the northern extension of the 60-percent line where all the evaporation lines are rather close together and nearly parallel. Ecologically, spring wheat could as well be grouped with the crops of the northeastern center, but geographically it belongs with the prairie climax. Edaphic considerations, then, rather than climatic, locate the area of spring wheat production. In Michigan and in Wisconsin the climate is as well suited to producing spring wheat as is the climate of those States farther west where production centers. Where spring wheat and barley are grown we find a great level tract of rich soil, a bequest of the old glacial Lake Agassiz. If wheat were a native plant indigenous to this climatic section of the United States, it would be found here a larger plant and in a greater variety of forms than in Michigan, where we may imagine its occurrence also. As however, it is a cultivated crop, the migration of which is controlled by man, we can see one valid explanation from among many others why its occurrence is limited in the way the chart shows. It is again a matter of profits.

While the eastward distribution is cut off sharply because of edaphic conditions, we can see in the climate only a vague and rather general determiner of the distribution north and south. This can be interpreted as meaning that physiological races have by no means approached the limits of their adaptability and convertability. Spring wheat, mostly durum, is found in both Nebraska and Kansas.

Oats center slightly north of the corn belt. Climatically, the center of production would be expected much farther northward. Edaphic reasons, and the convenience of a spring-sown crop rather than a fall-sown one to follow corn in the rotation now largely in practice in the corn belt push the center somewhat to the south.

This southward advance can only be accomplished by the introduction of small, early-maturing varieties which are able to make most efficient use of the available moisture. The commonly cultivated oats supposed to have arisen from the *Avena fatua* group of wild oats succeed in cool moist climates similar to that of their origin. While the origin of some of the early-maturing varieties is at present unknown, there is reason to believe that one at least, Burt,




SPRING WHEAT ACREAGE

[STATES ARRANGED IN DECREASING ORDER FOR 1909]

| STATE | CENSUS 1909 | ESTIMATE 1915 | STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|---|---|---|
| N. Dak. | 8,095,714 | 8,350,000 | Mont. . | 130,777 | 600,000 |
| Minn. . | 3,207,875 | 4,250,000 | Wis. . . | 78,563 | 105,000 |
| S. Dak. | 3,151,946 | 3,600,000 | Kans. . | 60,721 | 50,000 |
| Wash . | 1,136,321 | 890,000 | Utah . . | 58,475 | 75,000 |
| Iowa . . | 290,069 | 275,000 | Cal . . . | 51,812 | No estimates |
| Nebr. . | 233,024 | 346,000 | Wyo . . | 29,433 | 65,000 |
| Colo . . | 214,151 | 250,000 | Ill . . . . | 19,578 | No estimates |
| Idaho . | 147,844 | 280,000 | N. Mex. | 18,890 | 45,000 |
| Oreg . . | 141,655 | 225,000 | Nev. . . | 11,547 | 34,000 |

SPRING WHEAT ACREAGE

(Continued)

| STATE | CENSUS 1909 | ESTIMATE 1915 |
|---|---|---|
| Mich . | 8,531 | No estimates |
| Tex . . | 5,448 | No estimates |
| Mo. . . | 4,089 | No estimates |
| N. Y. . | 3,307 | No estimates |
| Me. . . | 2,792 | 4,000 |
| Okla. . | 2,009 | No estimates |
| Ind. . . | 1,956 | No estimates |
| Ariz. . | 1,929 | No estimates |
| Pa . . . | 1,214 | No estimates |
| Ohio. . | 669 | No estimates |
| Vt . . . | 395 | 1,000 |
| W. Va. | 104 | No estimates |
| Other. | 272 | No estimates |
| East. . | 117,342 | 110,000 |
| West . | 16,993,768 | 19,335,000 |
| U. S. . | 17,111,110 | 19,445,000 |

FIG. 9. Map of the United States showing spring wheat acreage. Note the distribution is cut off sharply east and west, while north and south there is no marked line where production ceases. See text for discussion. From 1915 Yearbook of the U. S. Dept. of Agriculture.

may have come from *Avena barbata*. This is a group that offers opportunity for valuable genetic and systematic study.

The region south and east of the 100-percent rainfall-evaporation ratio line is ecologically known as the southeastern evergreen center. While the rainfall throughout this part of the country is greater than it is northward, higher temperatures cause much more rapid evaporation. The physiological water requirement is higher.

Cotton is the principal crop plant of this region. Eastward the extension of the southern Appalachians makes too rough a topography for the production of a cultivated crop. Temperature is the limiting factor of production northward; moisture is the limiting factor westward beyond central Texas. For present purposes the southern boundaries of Kentucky and Virginia may be considered the limit of cotton production, although there is a slight acreage in both of these States (fig. 10).

There is not space to give in detail all the crops produced in this region or to dwell on their ecological significance. The study of the maps (figs. 5 and 10) shows beyond doubt that the cotton belt and the southeastern evergreen forest are two names for the same region. The same influences operating to make this country distinct biologically operate in the determination of the crops produced here. For other crop charts the reader is referred to the 1915 Yearbook of the United States Department of Agriculture, from which the maps reproduced here were obtained. It is suggested that the same principles of grouping the maps employed here be followed when the other crop charts are examined.

It is interesting to note that although cotton is a cash crop and can be converted into money more easily than most crops of the country, yet even with this advantage competition with other crops prevents cotton from reaching the limit of production. These crops are: Tobacco in North Carolina and Tennessee, sugar cane and rice in Louisiana, rice in Texas and sweet potatoes, cowpeas, and peanuts in most of the States included by the cotton belt.

The northeastern evergreen forest lies to the north and east of the 110-percent evaporation line. It is in area the most extensive of the centers, spreading southward down the Appalachians into Georgia and Alabama, westward through Ontario, northern Michigan, Wisconsin, and Minnesota, and continuing northwest to the Bering Strait, with a more northerly distribution than the western plant formations. (See fig. 5.)

From the point of view of farm crops this center is restricted to

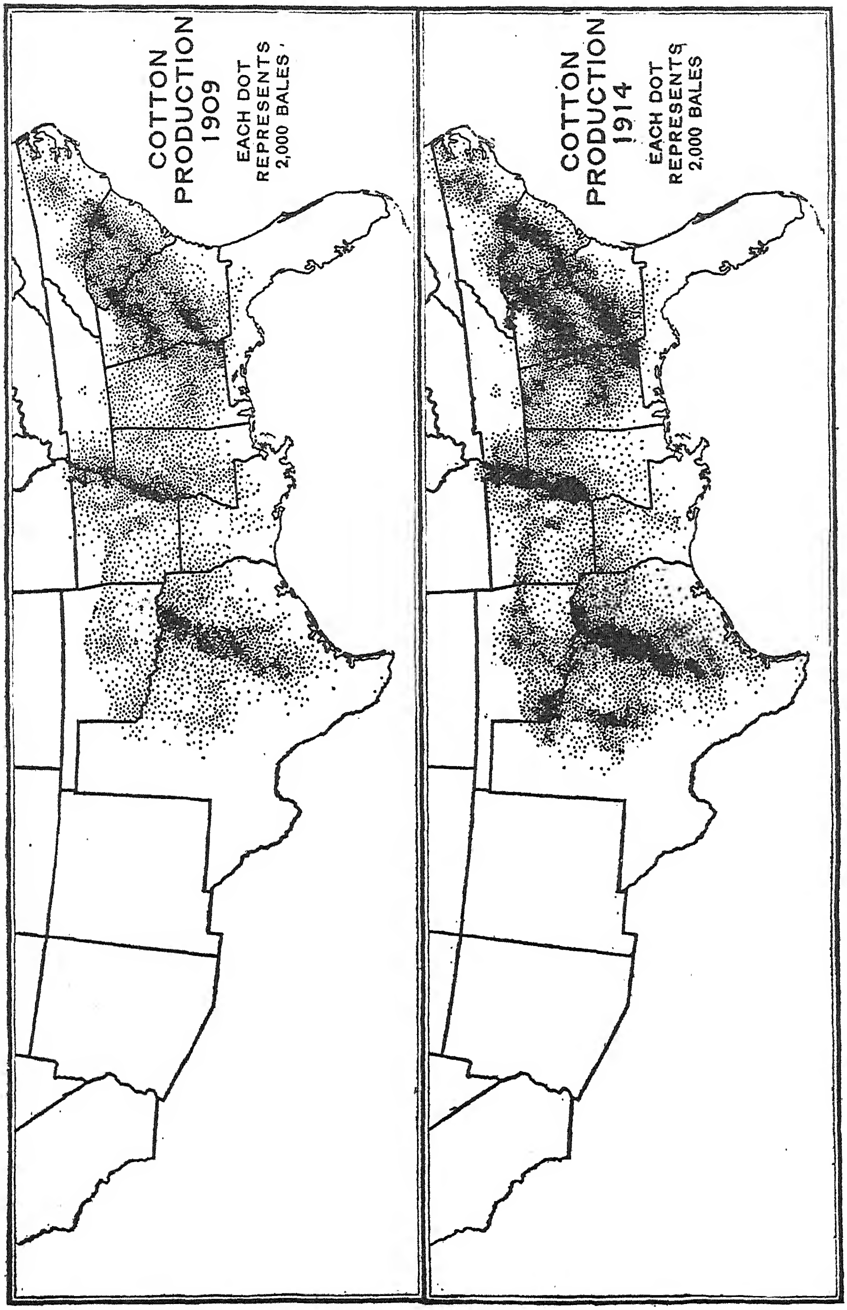
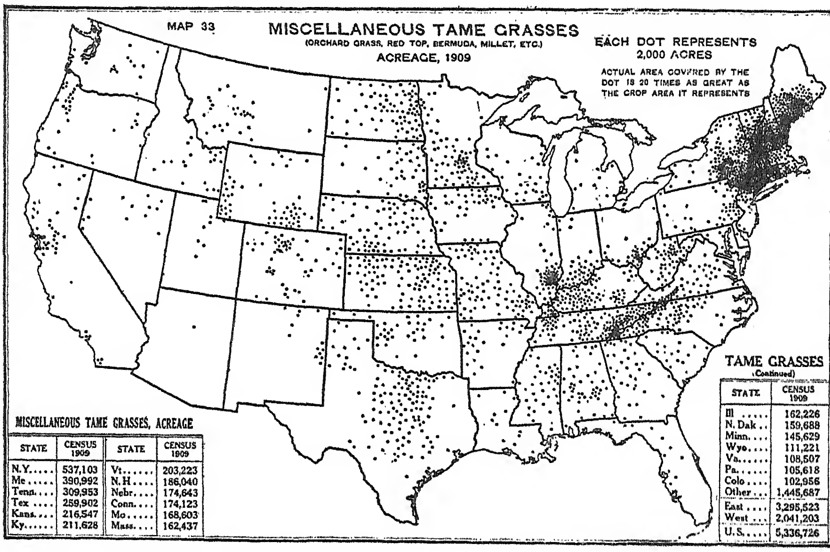



FIG. 10. Cotton production in 1909 and 1914 compared. Note the geographic relation of the cotton-belt States to the corn-belt States. Compare with figure 5. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

New England and New York, extending through certain sections of Pennsylvania. This is the tame hay and pasture region of the United States. When it is again noted how closely the prairie-plains climax and the northeastern evergreen climax approach one another in the Dakotas and Minnesota, the problem of placing spring wheat will be appreciated. The reasons for discussing this crop under the prairie-plains climax have already been given.

In New York and New England over 50 percent of the improved land is in hay or some forage crop (fig. 11), while if the pasture land is added to this it will be found that from 80 to 90 percent of the improved land is in pasture, hay and forage.




| STATE | CENSUS 1909 | STATE | CENSUS 1909 |
|---|---|---|---|
| N.Y. | 537,103 | Vt. | 203,223 |
| Me. | 390,992 | N.H. | 186,040 |
| Tenn. | 309,953 | Nebr. | 174,643 |
| Tex. | 259,902 | Conn. | 174,123 |
| Kans. | 216,547 | Mo. | 168,603 |
| Ky. | 211,628 | Mass. | 162,437 |

| STATE | CENSUS 1909 |
|---|---|
| Ill | 162,226 |
| N. Dak | 159,688 |
| Minn. | 145,629 |
| Wyo. | 111,221 |
| Va. | 108,507 |
| Pa. | 105,618 |
| Colo | 102,956 |
| Other | 1,445,687 |
| East | 3,295,523 |
| West | 2,041,203 |
| U.S. | 5,336,726 |

FIG. 11. Acreage of miscellaneous tame grasses. These include orchard grass, redtop, Bermuda, millets, and others. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

The climatic reason for the great and increasing production of fodder in this region is that the lower temperatures make cereal production less profitable than in the respective centers of these crops. This brings out clearly the rather strange fact that although both wheat and oats are climatically adapted for this center, maize is the premier cereal of America and seems to serve as a foundation upon which the production of the other cereals is built. Edaphically the thin, stiff soils of this center and the uneven topography limit the production of crops that must be cultivated. Timothy is

the leading hay crop. Timothy and red clover are grown together for mixed hay, but clover alone is not so important in this center as it is in the alluvial soils of the lower Ohio and Wabash basins.

Rye is an important grain crop of the northeastern center and in time of want could be made an appreciable source of breadstuff. Since rye bread is already known favorably to many people the fancied hardship of having bread that is not snow white could probably be overcome with rye flour sooner than with some other kind of wheat substitute. In Germany and Russia rye and wheat have been used interchangeably for years. Buckwheat also is important in this region and if demand came for it, production could be increased. It should be noted that buckwheat is the only crop cultivated for its edible grain that remained centering in the east during the time that the cereals have been carried westward.

The center of white potato production, while of course being dispersed in the neighborhoods of towns and cities for economic reasons that seem to take on more weight than the fundamental climatic and edaphic considerations, appears nevertheless to establish a fairly close relation with the northeastern evergreen center. This means that of the crops now used for that purpose the potato is the principal one for human food that is produced in this center. Potatoes seem, more than most plants, dependent upon soil conditions. Extensive investigations are now in progress to discover the varieties best suited to particular edaphic situations. Besides New England, another center of potato production is seen in the intermountain basin in Colorado wherever the natural moisture or irrigation makes its growth possible.

### B. THE PLAINS.

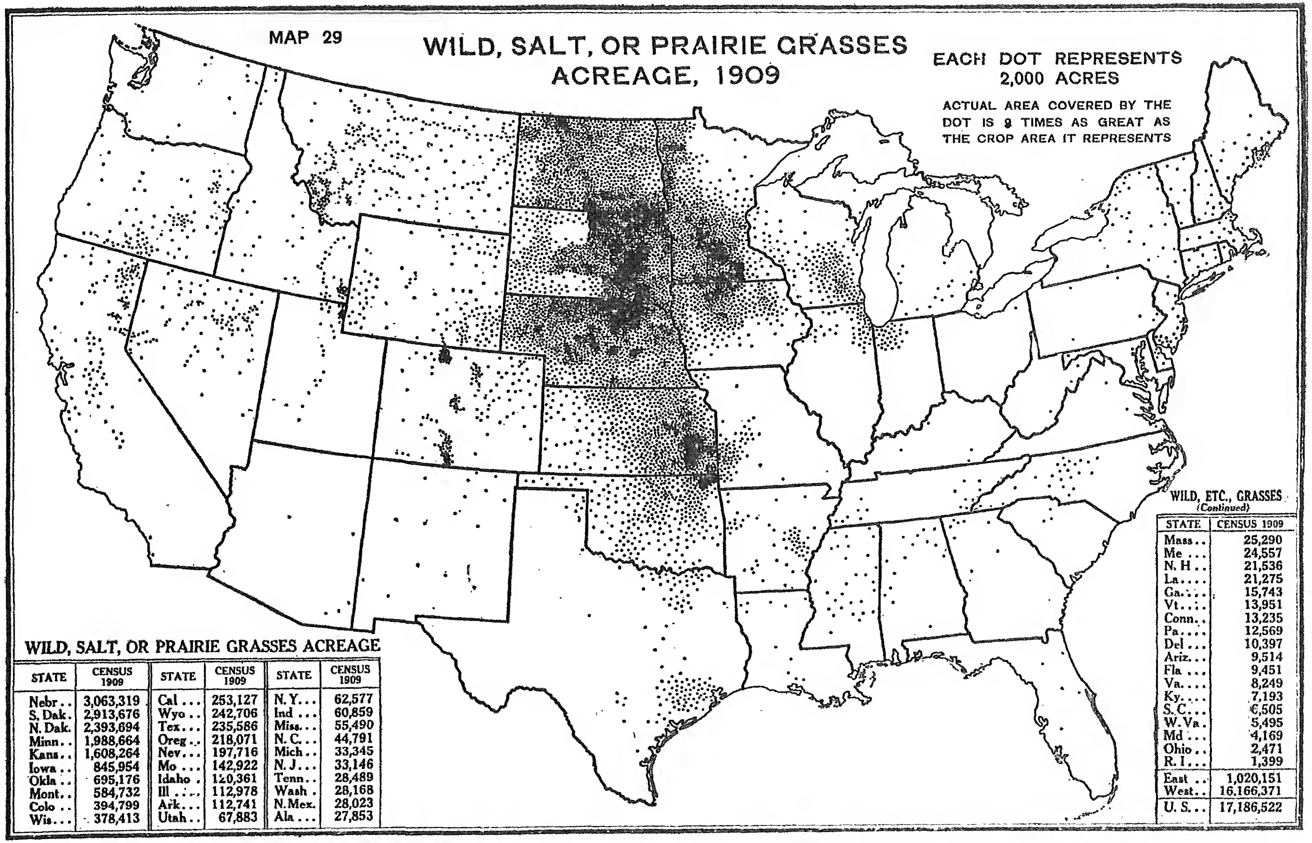
Turning now to the western half of the United States we find that throughout by far the greatest portion of this area evaporation consistently exceeds precipitation two or more times. In order to live under such drought conditions plants must conserve water in an extreme degree. The effect of the limited moisture in determining the plant forms which best succeed in the face of this aridity is illustrated by contrasting the barrel cactus and the elm. The former is almost spherical and compacted into the least possible evaporating surface, the latter with its deliquescing trunk melts into many branches and leaves spread to the lightest breeze. The cultivated plants of the plains climax must be grown under the best known methods for saving and utilizing all the water that can be captured by the soil and under irrigation.

Climatically the plains mark a step toward greater drought than the prairies, just in the same way that the prairies are more arid than the forests. The plains lie west of the 60-percent rainfall-evaporation line, extending to the 20-percent line. The latter follows in general the north and south trend of the mountains at their eastern base (fig. 5). The severe continental climate that prevails is characterized by the high winds, sudden changes in temperature, and the unequal and slight distribution of the precipitation both summer and winter. It is this unequal distribution that renders ineffective much of the moisture that is precipitated. In the southwestern part of the plains where temperature and evaporation are greatest there is a gradual and imperceptible merging into desert conditions.

The direction of the prevailing winds is not such as to bring the moisture (in the form of an evaporation-reducing blanket of air, rather than actual precipitation) from the Gulf of Mexico, the Atlantic, and the forest of eastern America near the Plains. This might be stated in another way by saying that after the moisture from the east reaches the prairies it is dissipated into the higher air currents caused by the absorption and radiation of heat by the great land mass of North America. The discussion of "climatic origins" has already indicated this feature of continental climates.

Kansas is divided by the 60-percent evaporation line, so the agriculture of the east and west section of this State may be examined for the effects of moisture. In the east there is still sufficient moisture for the production of corn and the other crops commonly grown under the general methods of farming of the eastern United States. West of the line there is not sufficient moisture for this sort of farming and a quarter of a century ago the land had no agricultural value except for grazing. It has been pointed out that in Illinois is an edaphic plains area that is in agricultural essentials similar to the climatic plains region.

A revaluation of the land and a reorganization of agricultural practice was effected by the introduction into western Kansas of such efficient users of water as alfalfa, milo, and kafir. Land which was regarded 25 years ago as nearly useless cannot be bought under $50 an acre now. The system of farming that must be practiced in these lands of little water precludes the possibilities of a crop of even the water-conserving plants every year. The land is sometimes fallowed and allowed to accumulate moisture for a full crop every second year, as this has been found a more profitable method than growing a partial crop each year.




WILD, SALT, OR PRAIRIE GRASSES ACREAGE

| STATE | CENSUS 1909 | STATE | CENSUS 1909 | STATE | CENSUS 1909 |
|---|---|---|---|---|---|
| Nebr.. | 3,063,319 | Cal... | 253,127 | N.Y... | 62,577 |
| S. Dak. | 2,913,676 | Wyo.. | 242,706 | Ind... | 60,859 |
| N. Dak. | 2,393,694 | Tex... | 235,586 | Miss... | 55,490 |
| Minn.. | 1,988,664 | Oreg.. | 218,071 | N.C... | 44,791 |
| Kans.. | 1,608,264 | Nev... | 197,716 | Mich.. | 33,345 |
| Iowa.. | 845,954 | Mo... | 142,922 | N.J... | 33,146 |
| Okla.. | 695,176 | Idaho. | 120,361 | Tenn.. | 28,489 |
| Mont.. | 584,732 | Ill.... | 112,978 | Wash. | 28,168 |
| Colo.. | 394,799 | Ark... | 112,741 | N.Mex. | 28,023 |
| Wis... | 378,413 | Utah.. | 67,883 | Ala... | 27,853 |

WILD, ETC., GRASSES (Continued)

| STATE | CENSUS 1909 |
|---|---|
| Mass.. | 25,290 |
| Me... | 24,557 |
| N.H.. | 21,536 |
| La.... | 21,275 |
| Ga.... | 15,743 |
| Vt.... | 13,951 |
| Conn.. | 13,235 |
| Pa.... | 12,569 |
| Del... | 10,397 |
| Ariz... | 9,514 |
| Fla... | 9,451 |
| Va.... | 8,249 |
| Ky.... | 7,193 |
| S.C... | 6,505 |
| W.Va. | 5,495 |
| Md... | 4,169 |
| Ohio.. | 2,471 |
| R.I... | 1,399 |
| East.. | 1,020,151 |
| West.. | 16,166,371 |
| U.S... | 17,186,522 |

FIG. 12. Grasslands from which the natural vegetation can be used as hay or pasture. Note the proximity to the 60 per-cent evaporation line. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

In western Kansas the soil is permanently dry below a depth of 5 or 6 feet. In eastern Colorado a depth of 2 feet or perhaps less would bring one to the same condition. This comparison not only emphasizes the change toward greater aridity but indicates also the differences in possible crop production. It must be borne in mind that in all of these divisions of the United States there are many factors in operation which modify locally the influence of the climate. The data from agricultural experiment stations will continue for a number of years to be so meager that it will indicate crop possibilities in only the barest outline. It is safe to predict that production is likely to increase in this part of the country. The introduction of new plants suited to the conditions is going on at a surprising rate. Methods of studying the environment are improving and cooperation between the workers in different fields of endeavor is becoming greater.

Grazing and pasturing and the production of forage are the prin-cpial agricultural activities of the Plains climax. The wild hay and native pasture grasses must still be given the leading position in crop rank (fig. 12). Among the planted crops, alfalfa is easily first. The chart of alfalfa production shows its importance near the 60-percent evaporation line. Farther west, centers of production can be regarded as irrigated localities, or as regions where the intermountain rain and snow make its existence possible. South of the principal alfalfa center, but still near the 60-percent evaporation line, coarse forage is extensively produced. This part of the southwest plains has not reached the semidesert conditions of New Mexico and Arizona.

Charts of plains crops, i. e., alfalfa, plains wild grasses, and such coarse forage as milo and kafir, indicate subdivisions of a region where the gross physiognomy of the vegetation is largely the same. The divisions of the plains are ecologically related to the prairie and the forest centers in a way that corresponds to the relations brought out by the plant geographers studying the prairie-plains vegetation.

### C. THE PACIFIC COAST.

The third distinct climatic division of the United States is the narrow strip of territory from the Pacific Coast to the mountains. It may be rather roughly divided into a northern and a southern half. The northern half is the region of greatest rainfall in the United States, more than a hundred inches being recorded as the annual average. Under the heading of the Pacific Coast the intermountain basins east of that region may be mentioned because of

their geographic relations with this area. It should be understood that in these basins there are great variations in both moisture and temperature conditions. In general, it may be said that evaporation increases from north to south. This brings out the fact that these intermountain basins have their climatic counterparts in one of the three general climatic divisions. When more complete evaporation studies have been made, data will be at hand by which the exact climatic nature of each of these localities can be determined.

The proximity to a large water reservoir and the direction of the mountain chains and of the prevailing winds are the features which express themselves in the abundant rainfall of the Pacific Coast. In the northern part where the rainfall is greatest and evaporation least a super-forest develops. Douglas fir and one of the cedars form this giant forest. Weaver (1914) has traced the development of the vegetation in eastern Washington and Idaho and finds that the subclimax is composed of Pseudotsuga and Larix, often with *Abies grandis*. The real climax consists of the cedar, *Thuja plicata*, consociation. On the lower levels a scrub forest, or as it is more familiarly known, the chaparral, predominates. We are safe in believing that in the scrub forests evaporation begins to exceed rainfall and the moisture obtainable from the melting snows. In the extreme south and not a great distance from the coast is the desert.

The topography limits the distribution of the sequoias, which are to be found only near the mouths of the canons where there is exposure to the foggy atmosphere, protection from excessive evaporation, and the possibility of obtaining water circulating underground within reach of their roots. Topography also determines largely the evaporation and so controls the vegetation of the intermountain valleys. Some places are semideserts, even approaching desert conditions, e. g., the Snake River. Others present edaphic plains, prairie, or forest climaxes.

The northern part of the Pacific Coast is primarily a hay-prdoucing region just as is New England. There is a notable feature peculiar to this region due to the abundant rainfall. It is the customary practice to use for hay plants the same crops which in the Middle West are grown mainly for their grain. Wheat and barley are used as forage crops and are classed by the census enumerators as "grains cut green." It is also possible that some day the center of the bulb-growing industry for the United States may be located in favorable situations in this part of the country. The apple industries of the moister river valleys of Washington, Oregon, and Idaho are famous

all over the world. In a number of localities in this region enough wheat is grown to make an important wheat center.

In the southern part of the Pacific Coast region annual crops are largely replaced by tree crops, walnuts, citrus fruits, olives, and other perennials.

### Animal Centers.

This account would not be complete without some reference, however slight, to the animal industries that follow the production of plants. The reader is urged to examine the charts on livestock in the 1915 Yearbook of the United States Department of Agriculture and compare them with the rainfall-evaporation ratio chart and the crop centers.

Adams (1915) has shown that the insect communities of a forest and a prairie are totally different. This indicates the same adjustment to physiological requirements that has been seen in the plants. It also indicates something of the dependence of animals upon certain plants for their food. The interrelations between plants and animals growing out of this fundamental dependence are enormous. Adams's report will have to be read in full to appreciate something of it. Back of the interrelations between plants and animals is the relation of both to the physical factors of their environment.

The presence of certain wild plant species in a locality is sufficient to account for the occurrence of insect species (Adams, 1914, loc. cit., p. 46). It is a more widely known fact that the introduction of wheat into America was shortly followed by the introduction of the Hessian fly. This insect has spread everywhere by following the path of its favorite food plant. It is almost a foregone conclusion that a map showing the limits of wheat distribution would also show the limits of the distribution of the Hessian fly. The Colorado potato beetle was able to spread to all parts of the United States because paths had been made for it by planting potatoes and one of these happened to touch a natural center for the beetle. Such instances as these could easily be multiplied.

We might perhaps be inclined to believe that the adjustments of animals to plant development could most easily be found among the insects, a numerous and highly specialized group. But the responses are universal and are to be seen whether we go up or down the evolutionary scale. Adams reports prairie and forest spiders and snails, while Hankinson (1915) distinguishes the forest vertebrates, ranging from fish to mammals, from the prairie vertebrates, ranging from

amphibians and reptiles to mammals. The work of Thompson-Seton (1909) on the North American mammals should also be consulted in this connection. Many charts of both herbivorous and carnivorous animals, together with many notes on their distribution, are presented in the two volumes of his work. These maps show that the biological centers may be examined from many angles, depending upon the particular field of endeavor of the worker, but that, after all, the centers are expressions of the same interactions of climatic and edaphic factors. The distribution of the striped ground squirrel, *Citellus tridecemlineatus,* marks the prairies. Its range carries it across Illinois eastward into Indiana and Ohio, and it is also seen in the sand plain of southern Michigan. In the plains, the prongbuck, *Antilocapra americana,* has its food habits fixed by its environment. In captivity attempts to give it other food than the familiar grass, cactus, and sagebrush have proven unsuccessful.

Much more readily observable is the dependence of the domesticated animals upon the cultivated plants. Reference to the charts in the 1915 Yearbook will show that the dairy industries are located in the northeastern evergreen center and on the Pacific Coast. These regions it will be remembered are the natural tame hay and pasture centers of the United States. Economic reasons also enter into this, of course, but the significance of a cool moist climate with an abundant production of forage reasonably certain every year is too large a fundamental fact to overlook. Beef cattle and swine are found centering in and slightly west of the corn belt. Their relations to the great grain-growing areas are not difficult to perceive. The greatest production of horses is in the region just north of the corn belt. This is the present center of oats production also. Mules are supposedly sturdier work animals than horses. They are found centering in the cotton belt because, more in the past than at present, grain and fodder was not produced in the cotton belt and so good feed was difficult to get. Also, as their drivers were less likely to be careful of work stock, there was a greater chance of survival after ill treatment.

Sheep are abundant in the arid regions. Though production is greatest in the West, there is also an important center in Ohio and Pennsylvania. On the whole this distribution is most interesting and brings out several important facts. First it should be noted that the sheep of the East and Middle West are more likely to be mutton sheep and the wool produced is only a byproduct. Unfortunately

there is no way of determining easily just how far this is true. The distribution in the West must be regarded as climatic, since sheep can find a living from vegetation on which other animals would perish, and the western distribution shows sheep to be limited to the rather sparsely vegetated areas. Further, not only does climate determine the distribution of sheep, but it also controls the method of handling them. Because there is not enough vegetation to feed them in any one place, they must be driven to follow the growth of vegetation which springs up after the rainy seasons. This is especially true in Wyoming and Montana, the two greatest wool-producing States, and in the drier portions of Oregon and southern California.

The center in Ohio and Pennsylvania is significantly located east of the glacial boundary, where the rougher topography favors pasturing. In addition to pasture, access to grain and fodder is not difficult and the feeding of the sheep in winter is a part of the method of handling. The eastern Ohio and western Pennsylvania center of sheep raising is essentially an edaphic center.

Many of the statements in the foregoing paper can not be appreciated fully until the relation of the crop centers to the centers of the natural vegetation has been completely analyzed. The intensive methods used by the ecologists in the study of the habitat, namely, the use of instruments for the exact observation of the moisture and temperature and photographs to record plant growth in relation to the surroundings, can not be too strongly emphasized. In a number of instances the measurements found by ecologists who have used standardized vaporimeters are applicable to agricultural studies. In all studies of evaporation, edaphic factors sometimes operating with and sometimes against the climatic, deserve the most careful interpretation. These in turn are dependent upon the present and historic geology and topography.

## Summary.

The crop centers of the United States agree with the biotic centers. In detail this means that the corn and winter wheat belts correspond to the deciduous central forest and the prairie climaxes, the tame hay and pasture region to the northeastern evergreen forest, the cotton belt to the southeastern evergreen forest, and so on. The rainfall-evaporation ratio map is useful for the demarcation of these centers because in it are included four factors of climate, namely, relative humidity, temperature of the evaporating surface, and wind velocity

as the divisor, and precipitation as the dividend. These four factors are of profound importance to plant growth.

Edaphic factors frequently determine the distribution of the cultivated plants. Edaphic and climatic factors, although they may be independent of one another in their operation, sometimes cause the same agricultural practices to be employed. Economic factors modify the influence of climate and soils.

A fundamental difference between crop plants and the natural vegetation is seen when plants are found beyond their usual centers. The crops are found on the best soils only, since that is their sole chance to compete with other crops for profit. Plant invaders of the indigenous vegetation migrating from their centers can offer competition in the poorest habitats only. In the better habitats the plants belonging to the center are little influenced by invaders.

In addition to the exotic crops being given the best fields, further soil modifications are usually introduced. In the extreme cases, climatic as well as soil modifications are practiced. Field plants are then grown on a comparatively large scale under glass or cloth shelter.

The domesticated animals are grouped about the centers of production of those crops upon which they are most dependent.

The methods used in studying plant succession have been used here. It is in this field of research that an accurate interpretation of conditions as consequences of the operation of physical forces of the past and present has been made. Migration, including invasion and competition, the latter implying dominance, are the direct results of interaction of climate and soils upon vegetation.

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## CHANGES IN THE NITROGEN CONTENT OF STORED SOILS.[1]

WM. A. ALDRECHT.

Certain determinations for soil nitrogen at the Missouri Agricultural Experiment Station have shown marked evidence of increases having taken place during storage. As the soil samples in question had been stored in containers which were not airtight and as some of the samples were moist, the possibility of bacterial fixation at first suggested itself. As the room where the samples had been stored adjoined the laboratory in which more or less ammonia was being used it seemed more probable that the increase was due to direct ammonia adsorption.

Literature on the adsorption of gases by soils puts ammonia as one of the gases most easily adsorbed. Schlösing found that a moist soil exposed to the air adsorbed nitrogen at the rate of 38 pounds per acre per annum, which was mainly in the form of ammonia. This adsorption took place whether the soils were acid or alkaline, dry or wet (7).[2] A. D. Hall, of Rothamsted (1), after studying ammonia absorption from the air by means of sulfuric acid, states that "the maximum absorption per annum amounts to less than a pound per acre." In testing the amounts of ammonia that soils will adsorb from an unlimited supply, Muntz and Gerard found that 1 kilogram of garden soil took up 5.38 grams of ammonia (4). The

[1] Contribution from the Department of Soils, University of Missouri. Received for publication September 4, 1917.

[2] Figures in parentheses refer to papers similarly numbered in "Literature cited," page 88.

presence of various substances in the soil increases the adsorptive capacity for ammonia. It has been shown that calcium carbonate (7), ferric hydroxide, and organic matter (2) have marked effects, while moisture is not as effective as one would suppose (6).

Lyon, Fippin, and Buckman (3) state that—

> Absorption of gases by soils is largely an adsorption phenomenon, the gases being condensed on the surface of the particles. The absorption is greater, the finer the particles of soil, but this increase is not directly proportional to the increase in surface, large particles apparently having a greater absorptive power than their surface would indicate.

As a surface phenomenon the amount adsorbed will be dependent on such factors as partial pressure, temperature, viscosity of the vapor, physical condition, chemical composition, and others. When the gases are once adsorbed, they are maintained with marked tenacity, as is shown by glass, which holds hygroscopic moisture at temperatures as high as 500° C. Sufficient evidence is available to emphasize the fact that the soil is a powerful adsorber of gases. This mass of information suggested the possibility of contamination of stored samples through this means. The following study was undertaken to find out whether contamination by adsorbed ammonia or bacterial activity was responsible for variation of the nitrogen in stored samples.

The plan of storage and treatment of the soil was as follows. Two soils widely different in nitrogen content were collected; one a Shelby silt loam with 2,325 pounds, and the other a Summit clay loam with 7,950 pounds of nitrogen in 2,000,000 pounds of surface soil. Each sample was thoroughly mixed and divided into three parts. On one part the determinations of nitrate, ammonia, and total nitrogen were made as soon as possible after collecting. The second part was put into a room adjoining the general soils laboratory and spread out on a table. Determinations of the three forms of nitrogen were made four weeks later. The third portion of the soil was put into bags in the moist condition and stored in a basement room to dry slowly for analysis two months later.

The analytical methods were those commonly used. Nitrates were determined by extracting the over-dried soil with $\frac{N}{16}$ hydrochloric acid, making it alkaline, boiling off the ammonia, reducing with Devarda's metal, and distilling. The ammonia was measured by distilling the soil and magnesium oxide with compressed air and steam, while the total nitrogen determination was according to the

official method modified for nitrates by use of sodium thiosulfate. The samples were thoroughly mixed each time and sieved through an 80-mesh sieve for total nitrogen determinations and through a 20-mesh sieve in the other cases. All determinations were calculated on a water-free basis. Each sample for total nitrogen was dried in an oven at 107° C. for eight hours and then transferred to a flask for digestion. Calculations of pounds per acre were based on each separate water-free sample. For receiving nitrate and ammonia distillations, a $\frac{N}{28}$ sulfuric acid was used and duplicates checked within 0.2 c.c. for the nitrates but not so closely for ammonia. For total nitrogen analysis a $\frac{N}{14}$ acid was used, and determinations again checked to 0.2 c.c. All samples except in a few cases were run in quadruplicate.

Table 1 gives the data from the different nitrogen determinations. The figures are averages calculated from four determinations.

TABLE 1.—*Variation in amounts of ammonia, nitrate, and total nitrogen of a soil stored under different conditions.*

AMMONIA NITROGEN.

| Date of determination and place stored. | Silt soil. Weight of water-free soil. | Silt soil. Nitrogen. | Clay soil. Weight of water-free soil. | Clay soil. Nitrogen. |
|---|---|---|---|---|
| | *gms.* | *mgs.* | *gms.* | *mgs.* |
| On day sampled | 82.60 | 1.53[a](1.48–1.58) | 71.55 | 1.50(1.30–1.73) |
| Dried 28 days near laboratory | 83.28 | 2.31(2.14–2.50) | 80.37 | 2.66(2.57–2.72) |
| Dried 56 days in basement | 82.70 | 1.45(1.32–1.60) | 78.95 | 1.58(1.47–1.73) |

NITRATE NITROGEN.

| Date of determination and place stored. | Silt soil. Weight of water-free soil. | Silt soil. Nitrogen. | Clay soil. Weight of water-free soil. | Clay soil. Nitrogen. |
|---|---|---|---|---|
| On day sampled | 61.97 | Trace | 53.66 | Trace |
| Dried 28 days near laboratory | 63.68 | Trace | 61.45 | 0.310(.255–.357) |
| Dried 56 days in basement | 63.24 | Trace | 60.37 | 0.340(.255–.408) |

TOTAL NITROGEN.

| Date of determination and place stored. | Silt soil. Weight of water-free soil. | Silt soil. Nitrogen. | Clay soil. Weight of water-free soil. | Clay soil. Nitrogen. |
|---|---|---|---|---|
| On day sampled | 9.79 | 10.96(10.69–11.12) | 9.480 | 37.64(37.45–37.84) |
| Dried 28 days near laboratory | 9.80 | 11.32(11.19–11.49) | [b]9.46 | 39.32(39.19–39.48) |
| Dried 56 days in basement | 9.73 | 11.21(11.09–11.38) | 9.29 | 37.77(37.58–37.92) |

[a] Figures in parentheses denote limits of variations in figures from which averages were calculated. Variations in hygroscopic moisture determination were less than 6 milligrams for the 10 gram samples.

[b] Three determinations only.

The total nitrogen on the day sampled in the silt soil was 2,237 pounds per acre in 2,000,000 pounds of surface soil, variations 2,183 to 2,263 pounds; in the clay soil, 7,943 pounds (7,901–7,981). In the soils dried 28 days in the laboratory, the total nitrogen was, silt soil, 2,311 pounds (2,284–2,345), and clay soil, 8,315 pounds (8,286–8,350). In the soils dried 56 days in the basement, the total nitrogen was, silt soil, 2,306 pounds (2,280–2,339), and clay soil, 8,133 pounds (8,097–8,164).

The data given for the ammonia nitrogen in Table 1 indicate an increase in this form when the soil was dried near the laboratory, while there was no increase when stored in the basement room. This indicates contamination by gaseous ammonia rather than bacterial action, for if the latter agent had been responsible the sample stored in the basement should have given an increase in ammonia also. Bacteria seemed to be playing no rôle in a measurable way.

The nitrates remained largely unaffected by storage, even though the clay loam shows less nitrogen as nitrate on the day of sampling than when stored. No explanation for this is offered.

The total nitrogen showed an increase with storage, particularly when the soil was kept near the laboratory. With silt soil this increase was small, but with the clay loam quite significant, though the determinations are a trifle erratic in the latter case. The data as a whole indicate that there is no significant change in the nitrogen by bacteria.

The above results prompted another series of analyses on the silt soil only, to test the possibility of contamination of both moist and dry soils by ammonia. Several portions of a large sample of soil were treated as follows. One part was analyzed for ammonia and total nitrogen as soon after sampling as possible. A second portion was dried in the laboratory where ammonia was used. The third part was dried in a greenhouse located in an orchard away from any ammonia. As soon as the soil in the greenhouse was well dried, analyses were made on some of it, and the remainder was divided into halves, leaving one half in the greenhouse and transferring the other half in the laboratory where it was spread out near an evaporating dish containing about 60 c.c. of ammonium hydroxide. This procedure was followed since no ammonia was being used in the room at that time. The data are given in Table 2. Determinations were made in sets of four and figures given are averages.

TABLE 2.—*Ammonia and total nitrogen in silt soil as affected by different conditions of storage.*

| Time of sampling and place stored. | Ammonia nitrogen. | | Total nitrogen. | | |
|---|---|---|---|---|---|
| | Water-free soil. | Nitrogen in sample. | Water-free soil. | Nitrogen in sample. | Nitrogen in 2,000,000 pounds of surface soil. |
| | *Grams.* | *Mgs.* | *Grams.* | *Mgs.* | *Pounds.* |
| Fresh soil | 79.73 | 1.01 [a](0.86–1.12) | 9.6609 | 11.248 (11.189–11.288) | [b] 2,328 (2,317–2,335) |
| Dried in greenhouse 10 days | 77.85 | 1.23 (1.07–1.37) | 9.7320 | 11.275 (11.189–11.388) | 2,316 (2,298–2,340) |
| Dried in laboratory 10 days | 77.91 | 2.91 (2.75–3.11) | 9.7382 | 11.474 (11.437–11.537) | 2,356 (2,348–2,370) |
| Dried and stored in greenhouse | 78.13 | 1.72 (1.65–1.78) | 9.7662 | 11.409 (11.371–11.468) | [c] 2,337 (2,328–2,347) |
| Dried in greenhouse and stored in laboratory near ammonia | 78.30 | 60.43 (60.04–60.81) | 9.7878 | 19.041 (18.823–19.114) | 3,890 (3,846–3.906) |
| Dried in greenhouse and stored near ammonia; samples not heated | | | [d]9.7878 | 18.823 (18.678–18.969) | [c] 3,846 (3,816–3,876) |

[a] Numbers in parentheses denote range in variations. Hygroscopic moisture determinations varied no more than 6 milligrams in a 10-gram sample.
[b] Three determinations only.
[c] Two determinations only.
[d] Water-free soil figured from sample above.

The data in Table 2 show beyond a doubt that both the moist and dry soils have taken up nitrogen as ammonia when stored in a laboratory in which ammonia fumes are present in considerable amounts. The sample dried in the greenhouse and then exposed in a dry state to ammonia fumes adsorbed enough to give 1,553 pounds per acre increase in the total nitrogen. In the distillable ammonia there was an increase by drying in the laboratory and an unusual increase for the dry soil left near an ammonia container. The increase in ammonia nitrogen over the sample when first collected amounts to 1,517 pounds per acre, corresponding closely to the increase of 1,553 pounds per acre of total nitrogen. Evidently the use of small amounts of ammonia in the laboratory is sufficient to increase markedly the nitrogen in a soil exposed there. That the ammonia is not held by the moisture present in the soil is indicated by the increase of nitrogen

when the dry soil was brought from the greenhouse and stored near the ammonia. This soil had but 2.75 percent of moisture, yet took up the equivalent of 1,517 pounds of nitrogen per acre. Ammonia thus taken up is held strongly enough so that heating for eight hours at 107–108° C. does not drive it off. This is shown by the figures for those samples analyzed without first heating them in an oven as compared with those heated. That the nitrogen is taken up in the form of ammonia is shown by the fact that the increase of this element is distillable with magnesium oxide. In the form of ammonia, the nitrogen is held, not by moisture, but by adsorption as a purely physical phenomenon.

This brief study indicates that in case of soils stored in or near a laboratory in other than air-tight containers, there is a grave danger of contamination by ammonia, whether the soil is wet or dry. It indicates further that when moist soils are left to dry slowly there is little danger of bacterial action measurably affecting the nitrogen content.

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3. Lyon, T. L., Fippin, E. O., and Buckman, H. O.
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7. Schlössing, T.
   Comp. Rend. (Paris) 110: 429–499. *Abs. in* Expt. Sta. Record, 3: 110–112. 1891. *Cited by* King, F. H., The Soil, p. 122. Also *cited by* Patton and Gallagher (5), p. 30.

# NAMING WHEAT VARIETIES.[1]

CARLETON R. BALL AND J. ALLEN CLARK.

Crop varieties must be distinguished by names. These names must be used frequently by a host of agronomic workers as well as by crop growers and crop users. The form and appropriateness of these names, therefore, are of general interest. It is desirable that they be short, simple, and appropriate, easily spelled and pronounced. It also is desirable that a single name of this kind be designated and accepted for each recognized variety.

## CONFUSION IN VARIETAL NAMES.

The multiplication of names and other designations for crop varieties has been carried to great extremes. The resulting confusion also is very great, especially in those crops like wheat where the number of actual varieties is very large. These names and near names may be classified into three series, as follows: (1) Names, (2) descriptive phrases, and (3) numbers. As examples of names, Fulcaster, Fultz, Jones Fife, and Kubanka may be cited. As examples of descriptive phrases we may quote Bluestem, Early Red Clawson, Jones Paris Prize, Purple Straw, and White Australian. Numbers applied in place of names may be typified by Iowa No. 404, Minnesota No. 163, and Washington Hybrid No. 128.

At the present time, the existing confusion and multiplication of varieties places a great burden on agronomic workers. It renders uncertain and difficult the interpretation of published results of experiments. This confusion occurs in two principal ways. (1) The same name is applied to very different varieties in different parts of the country; (2) The same variety passes under several different names in different parts of the country, or even in the same part.

Good examples of the same name, or rather descriptive phrase, applied to different varieties are Bluestem and Red Russian. In the Far West, Bluestem is an awnless variety with glabrous white glumes and white soft kernels, usually spring-sown. According to Leighty, an eastern fall-sown variety with similar spike and kernel characters

[1] Contribution from the United States Department of Agriculture, Washington, D. C. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1917.

is known as Kentucky Bluestem. In the upper Mississippi Valley, Bluestem is a spring-sown awnless wheat with pubescent white glumes and red hard kernels. In the eastern United States, the names Alabama Bluestem and Georgia Bluestem are applied to fall-sown awnless wheats with glabrous white glumes and red, midsized, soft kernels, while Pennsylvania Bluestem differs in having brown glumes.

The descriptive phrase-name, Red Russian, is applied to four and perhaps five different varieties in this country. In the humid districts of the Pacific Northwest it is applied to a fall-sown variety with large, clavate, awnless spikes, glabrous white glumes, and red large soft kernels. In the Great Plains area and westward, the name Red Russian is commonly applied to the Russian winter wheats of the Crimean group, as Crimean, Kharkov, and Turkey. These have small fusiform awned spikes, white glabrous glumes, and red midsized hard kernels. In the northern part of the Great Plains area, the name Red Russian is applied to a spring-sown variety, similar in general appearance to the Crimean winter wheats, but differing in spring habit, glume characters, and semihard kernels. A fourth variety called Red Russian is grouped by Leighty with those eastern wheats having awnless spikes with glabrous brown glumes and red soft kernels. The list of names which have been applied to at least two different varieties is too long to present here.

The second case mentioned was where the same variety passes under two or more varietal names. Here the real difficulty is to prove that the varieties bearing different names are really identical. This is a much more difficult task than determining strikingly evident differences, and is completed only after careful study and comparison. Here too we must recognize that there are differences of performance not necessarily correlated with visible characters. For such cases the necssary allowance must be made.

There remain, however, many cases in which the identity of varieties bearing two or more different names is evident. The Crimean group of hard red winter wheats, the dominant crop in Kansas, Nebraska, and Oklahoma, is a good illustration. Alberta Red, Crimean, Kharkov, Malakov, Red Russian, Torgova, and Turkey are only different names for a single variety. It may be called Crimean, or Kharkov, or Turkey with equal accuracy. Beloglina, on the other hand, can be separated from these others on one minor character, namely, the longer beaks and squarer, more deeply notched shoulders of the glumes. Kanred, a pure line separated from

Crimean, C. I. No. 1437, was bred and named by the Kansas Agricultural Experiment Station. It is, however, a true Beloglina, and differs from other Beloglinas only in consistently higher yield, so far as known.

Another good illustration is the Pacific Bluestem, the dominant spring variety of the Columbia and Snake River basins in the Pacific Northwest. Research has shown it to be identical with the White Australian, which has been the dominant variety of California for fully 60 years.

In addition to the different kinds of confusion of names which have been discussed, there are many examples of objectionable names of other sorts. Many varietal designations are long and cumbersome descriptive phrases; for example, Early Red Clawson, Jones Silver Sheaf Longberry, etc. Others are equally long and cumbersome numbers, as, for example, Minnesota No. 169, Nebraska Hybrid No. 28, or Washington Hybrid No. 143. Another disadvantage in using numbers as names is that an error in a single numeral renders the variety unrecognizable.

The facts and conditions set forth in the preceding discussion can be amplified almost without limit. They seem to the writers to show the need for some concerted action on the part of agronomic workers. The writers are about to begin the publication of a classification of wheats. In it varietal names must be used and confusion in their use avoided. This means that duplication of the same varietal name for different varieties can not be recognized. Conversely, different names for the same variety must be eliminated.

## A Proposed Code of Nomenclature.

A brief but comprehensive code of nomenclature is presented herewith for the consideration of the members of the American Society of Agronomy. It is hoped that it may be adopted in some form at this meeting, so that the authors may have opportunity to select varietal names for their classification in accordance with its rules. In this way, whatever names are used would have the backing of a responsible body of agronomists.

## Code of Nomenclature.

The following rules governing the naming of varieties of crop plants are hereby proposed for consideration and adoption by the American Society of Agronomy, at the annual business meeting on November 13, 1917.

1. Eligibility to Naming. No variety shall be named unless (*a*) distinctly different from existing varieties in one or more recognizable characters, or (*b*) distinctly superior to them in some character or quality, and unless (*c*) it is to be placed in commercial culture

2. Priority. No two varieties of the same crop plant shall bear the same name. The name first published (see Rule 4) for a variety shall be the accepted and recognized name, except in cases where it has been applied in violation of this code.

A. The term, "crop plant," as used herein, shall be understood to mean those general classes of crops which are grouped together in common usage without regard to their exact botanical relationship, as corn, wheat, sorghum, cotton, potato, etc.

B. The paramount right of the originator, discoverer, or introducer of a new variety to name it, within the limitations of this code, shall be recognized.

C. Where the same varietal name has become thoroughly established for two or more varieties, through long usage in agronomic literature, it should not be displaced or radically modified for either one, except where a well-known synonym can be substituted. Otherwise the varieties bearing the same name should be distinguished by adding some suitable term which will insure their identity.

D. Existing American varietal names which conflict with earlier published foreign names for the same or different varieties, but which have been thoroughly established through long usage, shall not be displaced unless long-used and available synonyms exist.

3. Form of Names. The name of a variety shall consist of a single word.

A. Varietal names shall be short, simple, distinctive, and easily spelled and pronounced.

B. A varietal name derived from a personal or geographical name should be spelled and pronounced in accordance with the rules governing in the case of the original name.

C. The name borne by an imported foreign variety should be retained, subject only to such modification as is necessary to conform it to this code.

D. The name of a person should not be used as a varietal name during his lifetime. The name of a deceased person should not be so used except by the official action of this or other competent agronomic bodies. Personal names in the possessive form are inadmissible.

E. Names of stations, States, or countries, in either the nounal or adjectival form should not be used as varietal names.

F. Such general terms as hybrid, selection, pure-line, pedigreed, seedling, etc., should not be used as varietal names.

G. A number, either alone or attached to a word, should not be used as a varietal name, but considered as a temporary designation while the variety is undergoing preliminary testing.

H. Names which palpably exaggerate the merits of a variety shall be inadmissible.

I. In applying the provisions of this rule to varietal names which have become firmly established in agronomic literature through long usage, no change shall be made which will involve loss of identity.

4. PUBLICATION. A varietal name is established by publication. Publication consists (1) in the distribution of a printed description of the variety named, giving its distinguishing characters, or (2) in the publication of a new name for a variety properly described elsewhere, such publication to be made in any book, bulletin, circular, report, trade catalog, or periodical, provided the same bears the date of issue and is distributed generally among agronomists and crop growers; or (3) in certain cases the general recognition of a name for a commercial variety in a community for a number of years may be held to constitute publication.

A. Where two or more admissible names are given to the same variety, in the same publication, that which stands first shall have precedence.

5. CITATION. In the full and formal citation of a varietal name, the name of the author who first published it shall be given.

6. REVISION. No properly published varietal name shall be changed for any reason except conflict with this code, nor shall another variety be substituted for that originally described thereunder.

## EXPLANATORY COMMENTS ON THE RULES.

The first clause (*a*) of Rule 1 will prevent the recognition of several different names for the same variety. Clause *b* permits the naming of pure-line selections, hybrids, etc., which have superior merit, even though not distinguishable by external characters.

Rule 2 will govern the use of such names as Bluestem, Red Russian, etc., when applied to two or more different varieties. Paragraph C provides against confusion which would result from completely discarding well-known names.

Rule 3 governs the formation of acceptable names. Canadian and Australian wheat breeders have set a splendid example in the application of short, simple, and appropriate names to the varieties they originate. Names like Huron, Marquis, Prelude, Preston, Pioneer, and Stanley in Canada, or Bobs, Comeback, Federation, Firbank, and Warren in Australia leave nothing to be desired. The various explanatory paragraphs, A to I, inclusive, show how the rule is to be applied in special cases. The ultimate effect will be to do away with long, cumbersome, and oftentimes misleading descriptive phrases and selection numbers now used as names. Paragraph I prevents confusion through the complete loss of familiar names of long standing.

Rule 4 provides for the proper publication of varietal names. Williams[2] has given an admirable example of this in publishing his

[2] Williams, C. G. Wheat experiments. Ohio Agr. Expt. Sta. Bul. 298: 465–466. May, 1916.

three new varieties, Gladden, Portage, and Trumbull. Fuller descriptions will be desirable in official publication of new varieties.

Rule 5 is of little consequence and can be eliminated without serious loss. It merely gives some credit to the author of a varietal name when discussing a variety in any formal or important connection, such as description or classification, or in an alphabetical checklist of all known varieties. Some of the varieties mentioned above would then appear as follows: Marquis (Saunders); Bobs (Farrer); Monad and Buford (Ball & Clark);[3] Portage (Williams), etc.

Rule 6 governs changes of varietal names.

Copies of this proposed code have been sent to Prof. E. G. Montgomery, *chairman*, Prof. C. G. Williams, and Dr. H. K. Hayes, comprising the committee on varietal nomenclature of this Society. It is hoped that their discussion of it may be presented here before final action is taken.[4]

# AGRONOMIC AFFAIRS.

## ANNUAL DUES FOR 1918.

Those who have not already paid their dues for 1918 are urged to send checks promptly to the Secretary-Treasurer, P. V. Cardon, U. S. Department of Agriculture, Washington, D. C. Prompt remittance saves the Secretary-Treasurer much correspondence and insures continuous delivery of the JOURNAL. Under the by-laws of the Society, the JOURNAL is not to be sent after April 1 to those whose dues are not paid before that time. The sending of back numbers entails extra work on the officers and adds materially to the Society's expense account. If your dues are not already paid, remit now and get each number as it appears. Don't forget that the amount is $2.50. And be sure to notify the Secretary of any change of address.

[3] Ball, Carleton R., and Clark, J. Allen. Experiments with durum wheat. U. S. Dept. Agr., Bul. 618: 44, 46. 1918.

[4] The code, as here proposed, was adopted in its entirety, together with some additions proposed by the committee. It is published in the report of the committee (JOUR. AMER. SOC. AGRON., 9: 425–427. December, 1917).

## THE SOCIETY'S HONOR ROLL.

For some time, the Editor has planned to begin the publication of an honor roll of those members of the American Society of Agronomy who are serving their country in the world war. Following is the list of those who are known to the Editor to be in the military forces of the United States or of Canada. No doubt there are many more. If you know of some member of the Society in the army or navy or engaged in war work whose name is not on the roll here printed, inform the Editor and the addition will be made.

ROLL OF HONOR.

H. R. CATES,
A. D. ELLISON,
SAMUEL D. GRAY,
P. H. KIME,
E. E. GRAHAM,
LEROY MOOMAW,
J. V. QUIGLEY,
GEO. T. RATLIFFE,
L. C. RAYMOND,
F. J. SCHNEIDERHAN,
W. R. SCHOONOVER,
HERSCHEL SCOTT,
PAUL TABOR.

## MEMBERSHIP CHANGES.

The membership reported in the January issue was 653. Since that time 6 members have resigned and 9 new members have been added, a net increase of 3 and a total membership of 656. The names and addresses of the new members, names of the members resigned, and such changes of address as have come to the notice of the Secretary-Treasurer are reported below.

NEW MEMBERS.

EARL BURTIS, 325 East Olive St., Fort Collins, Colo.
BRUCE J. FIRKINS, Dept. of Soils, I. S. C., Ames. Iowa.
ALEX. GRANOWSKY, 320 Plum St., Fort Collins, Colo.
JEROME IGO, 228 W. Magnolia St., Fort Collins, Colo.
FRED MAIER, 400 S. Howes St., Fort Collins, Colo.
STERLING MINOR, 318 W. Magnolia St., Fort Collins, Colo.
GLENN PAXTON, Box 269, Fort Collins, Colo.
NELSON S. SMITH, School of Agr., Olds, Alberta, Canada.
R. E. STEPHENSON, Dept. of Soils, I. S. C., Ames, Iowa.

MEMBERS RESIGNED.

COBB, J. STANLEY,
GARLAND, J. J.,
JENSON, CHAS. A.,
POTTER, R. S.,
WOOD, M. W.,
ZERBAN, F. W.

CHANGES OF ADDRESSES.

ABELL, M. F., College of Agriculture, Storrs, Conn.
CURTIS, H. P., County Agent, Sutton, W. Va.
DUNNEWALD, T. J., 210 N. Carrol St., Madison, Wis.
GODDARD, L. H., 1324 Monroe St., Washington, D. C.
LUCKETT, J. D., States Relations Service, U. S. Dept. Agr., Wash.
MARIS, EDWIN I., Demonstration Agent, Atwood, Kans.
WARBURTON, C. W., 320 Flour Exchange, Minneapolis, Minn.

## NOTES AND NEWS.

George F. Corson, formerly professor of agriculture at the Iowa State Teachers' College, has been appointed assistant in soil survey at the Iowa station.

H. B. Derr, for the past several years county agent in Scott Co., Mo., is now county agent in Fairfax Co., Va., with headquarters at Fairfax.

R. A. Dutcher, formerly assistant professor of agricultural chemistry at the Oregon Agricultural College, and C. A. Morrow, formerly professor of chemistry at Nebraska Wesleyan University, are now assistant professors of biochemistry in the Minnesota college.

A. D. Ellison, for the past two years in charge of the cereal experiments on the U. S. Department of Agriculture's Arlington Farm near Washington, D. C., is now with the gas defense service of the U. S. Army.

J. N. Else has been appointed assistant in agronomy in the Pennsylvania college and station.

A. D. Faville, animal husbandman of the Wyoming station, has been elected director of the station, succeeding H. G. Knight.

R. L. Furry, a graduate of the Missouri College of Agriculture, is assistant plant breeder on the Ferguson Seed Farms, at Sherman, Texas.

S. C. Harmon is assistant agronomist at the Virginia station.

R. E. Holland, formerly county agent in Kimball Co., Nebr., has been made assistant emergency county agent leader and has been succeeded in Kimball County by Paul H. Stewart, instructor in agronomy in the Nebraska college last year.

H. G. Knight, for the past several years director of the Wyoming station and dean of the college of agriculture, has been elected to a similar position in the Oklahoma college and station.

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## THE EFFECT OF CERTAIN FACTORS ON THE CARBON-DIOXIDE CONTENT OF SOIL AIR.[1]

J. A. BIZZELL AND T. L. LYON.

### REVIEW OF LITERATURE.

It has been suggested[2] that some higher plants exert an influence on certain bacterial processes in the soil. Experiments indicate that some higher plants may, during the most active period of their growth, stimulate the formation of nitrates, while during the later periods of growth the same plants may exert a depressing effect. Since the conditions favoring the formation of carbon dioxide in soils are similar to those favoring nitrification, it is logical to suppose that the two processes would parallel each other.

Russell and Appleyard[3] have recently produced evidence to show that, so far as the effects of temperature, moisture, and apparently aeration are concerned, such a correlation probably exists. The presence of the growing plant, however, introduces so many far-reaching and disturbing factors as to make it difficult to institute such comparisons when based on the ordinary methods of analysis. In the first place, carbon dioxide is produced not only by simple oxidation but also by plants, while nitrates are absorbed by plants. Again, under

[1] Contribution from the Laboratory of Soil Technology, College of Agriculture, Cornell University, Ithaca, N. Y. Received for publication October 23, 1917.

[2] Lyon, T. L., and Bizzell, J. A. Some relations of certain higher plants to the formation of nitrates in soils. Cornell Univ. Agr. Expt. Sta. Memoir No. 1. 1913.

[3] Russell, E. J., and Appleyard, A. The influence of soil conditions on the decomposition of organic matter in the soil. *In* Jour. Agr. Sci., 8: 385–417. 1917.

soil conditions the carbon dioxide produced is distributed between the liquid and gaseous phases. As the relative amount contained in each case is dependent on the content of water, calcium carbonate, and dissolved salts, it becomes difficult to determine quantitatively the effect of any one factor on the amount of carbon dioxide produced. It has frequently been observed that carbon dioxide is excreted by the roots of plants and that this process is in some way closely connected with the period of greatest vegetative growth. That there may be more deep-seated effects is indicated by results obtained by the authors. Boussingault and Lewy, Pettenkofer, Foder, Moller, Ebermayer, and other early investigators observed that soil air contains more carbon dioxide than atmospheric air. This phenomenon was attributed generally to the oxidation of organic matter. The fluctuations in the carbon-dioxide content of the soil air were apparently governed by seasonal conditions. The effect of cropping appears to have been first studied by Wollny,[4] who placed calcareous sandy soil in metal cylinders and determined the carbon dioxide in the air once each week during the summer and part of the winter months. Comparing grass sod with bare soil, he found less carbon dioxide under sod during the summer months and more during the winter months. He attributes the effect of the crop to its effect on the moisture, temperature, and porosity of the soil.

Déhérain and de Moussy[5] called attention to the fact that carbon-dioxide formation in the bare soil is due almost wholly to bacteria. They found that sterile soil at ordinary temperatures produces little carbon dioxide but that at points much above 65° C. considerable oxidation occurs by purely chemical means. They obtained large quantities of carbon dioxide by spreading soil in very thin layers and concluded that aeration is one of the most important factors.

Molisch,[6] in studying root secretions, found an enzyme which has the power to oxidize the organic compounds of humus. Czapek,[7] working along similar lines, produced evidence to show that the plant-root excretion which gives the acid reaction is carbonic acid. Wollny[8]

[4] Wollny, E. Untersuchungen über den Einfluss der Pflanzendecke und der Beschattung auf dem Kohlensäuregehalt der Boden Luft. *In* Forsch. Geb. Agrik.-Physik., 3: 1–15. 1880.

[5] Déhérain, P. P., and de Moussy, E. Sur l'Oxydation de la Matiére Organique du Sol. *In* Ann. Agron., 22: 305–337. 1896.

[6] Molisch, H. Über Wurzelausschied und deren Einwirkung auf Organische Substanzen. *In* Sitzungs Akad. Wiss. Wien-Math. Nat., 96: 84–109. 1888.

[7] Czapek, F. Zur Lehre von der Wurzelausscheidungen. *In* Jahr. Wiss. Bot., 29: 324.

[8] Wollny, E. Die Zersetzung der Organischen Stoffe. 1897.

demonstrated that, in the absence of free oxygen, organic matter may reduce the oxides of manganese and iron and form carbon dioxide. He also states that certain organic substances may form carbon dioxide by simple decomposition. Kossowitsch[9] grew mustard in nutrient solution mixed with washed quartz. He dissolved the carbon dioxide produced by percolating nutrient solution through the containers. This was so regulated as to give 5 liters of percolate in 24 hours. A check container on which no plants were growing was included. The carbon dioxide in the planted mixture increased gradually up to the end of the experiment when the plant was in full bloom, while the check varied within narrow limits.

Stoklasa and Ernst[10] grew barley, wheat, rye, and oats in nutrient solutions and determined the amounts of carbon dioxide produced at different stages of growth. The younger the plants and more tender the roots, the greater the quantities of carbon dioxide produced per gram of dry matter. Considering the total amounts of carbon dioxide produced, however, they found the maximum with plants 70 to 80 days old. At 84 days there were somewhat smaller quantities than at 80 days. They determined the quantity of carbon dioxide given off as gas by soil during 200 days. As the soil was bare of vegetation the action was attributed to bacteria. They obtained something more than twice the quantity of carbon dioxide estimated to be produced by wheat during 100 days. In a later article,[11] they investigated the chemical nature of root secretions and found carbon dioxide to be the principal one.

Amberson[12] observed that the mucilaginous covering of the root hairs contains a saturated solution of carbon dioxide. Lau[13] determined the carbon-dioxide content of soil air by a modification of the Petterson-Palmquist apparatus. He found that plant-root respiration has a marked effect upon the amount of carbon dioxide. It increased with the growth of the plant, reaching a maximum at the blooming

[9] Kossowitsch, P. The quantitative determination of carbon dioxide produced by the roots of plants during the period of their development. *In* Jour. Expt. Agr. (Russia), 5: 482–493. 1904. Translation by J. Davidson.

[10] Stoklasa, J., and Ernst, A. Über den Ursprung die Menge und die Bedeutung des Kohlendioxyds im Boden. *In* Centbl. Bakt., II, Abt. 14, S. 723–736. 1905.

[11] Stoklasa, J., and Ernst, A. Beiträge zur Lösung der Frage der Chemischen Natur des Wurzelseketes. *In* Jahrb. Wiss. Bot., 46: 55–102. 1908.

[12] Amberson, J. H. Ein Beitrag zur Kentniss der Natur der Wurzelausscheidungen. *In* Jahrb. Wiss. Bot., 47: 41–56. 1909.

[13] Lau, E. Beiträge zur Kentniss der Zusammensetzung der im Ackerboden befindlichen Luft. Inaug. Diss. Rostock. 1906.

period. Potatoes and lupines gave larger amounts than other crops. This was attributed to the fact that potatoes and legumes have a higher rate of respiration. The carbon-dioxide content in cropped plats reached a maximum at the root zone, while in uncropped soil the content increased directly with depth of sampling.

Barakov[14] grew lupines, clover, barley, rye, wheat, peas, vetch, potatoes, and sugar beets in lysimeters. Several different types of soil were used. Samples of soil air were collected by attaching retorts which had been exhausted to the tubes at the bottom of the lysimeters. The carbon dioxide was then determined by absorption in standard barium hydroxide solution. The author found that the maximum carbon-dioxide content as a rule coincided with the period of blooming. Contrary to the opinions of others he considers that plants produce much greater quantities of carbon dioxide in soil than do bacteria. He compared two lysimeters on which clover was grown. Both were harvested on June 14, and immediately thereafter the carbon-dioxide content decreased rapidly. In one lysimeter the clover sod was plowed under and the carbon dioxide continued to decrease. In the other lysimeter the clover was allowed to grow and the carbon dioxide increased to a maximum at the second blooming. The greatest quantity of carbon dioxide produced by bacteria was 6.9 mgr. per liter, while the highest produced by plants was 27.3 mgr. per liter. Barakov quotes the work of Souprounenko as showing that lysimeters bare of vegetation produced less carbon dioxide than did those on which millet was grown.

Comparing the effect of soil type, Barakov found that the ability of a particular plant to produce carbon dioxide is greater the more fertile the soil, and concludes that the effect is due directly to the more active vegetative growth on the fertile soil. He found that although the respiration curve varies with different plants, the maximum carbon-dioxide production occurs at the time of maximum life activity of a plant.

Van Suchtelen[15] mixed 6 grams of calcium oxide with 6 kilograms of soil and found the carbon dioxide produced to be less in the limed soil. On the other hand, magnesium sulfate, ammonium sulfate, and superphosphate stimulated carbon-dioxide production. The exper-

[14] Barakov, P. The carbon dioxide content of soils during different stages of growth of plants. *In* Jour. Expt. Agron. (Russia), 11: 321–342. 1910. Translation by J. Davidson.

[15] Van Suchtelen, F. H. H. Über die Messung der Lebenstätigkeit der Aërobischen Bakterien im Boden durch die Köhlensäureproduktion. *In* Centb. Bakt., II, Abt. 28, S. 45–89. 1910.

iments were meager and no statement is made as to the time intervening between application of salts and determination of carbon dioxide.

Stoklasa,[16] in making a study of bacterial action in soil, concluded that the greatest production of carbon dioxide occurs in neutral or slightly alkaline soil abundantly supplied with air and readily assimilable plant nutrients.

Lemmerman and his associates[17] quote the work of earlier investigators as showing decreased production of carbon dioxide in soil to which calcium oxide and calcium carbonate were added. Lemmerman found that applications of 0.1 percent, 0.5 percent and 1 percent of quicklime decreased production of carbon dioxide for the first two weeks, while the 0.5 percent and 1 percent applications continued to have the same effect for eight weeks. They also used calcium carbonate in quantities chemically equivalent to the quantities of calcium oxide. They found quantities corresponding to 0.1 percent CaO to be stimulative while the larger quantities gave a decrease in carbon dioxide. They conclude that the decrease with the quicklime was due to direct absorption of the gas produced with formation of calcium carbonate. They call attention to what they consider the errors that arise in experiments of this kind (1) when carbon dioxide only is determined and methane ignored, (2) when calcium oxide absorbs the carbon dioxide formed, and (3) when calcium carbonate is applied to acid soil, causing evolution of the carbon dioxide from the carbonate added.

Leather[18] studied carbon-dioxide production in soil by determining the total carbon dioxide present in the form of a gas and in solution as $Ca(HCO_3)_2$. This was done by taking a small soil core 4 cm. by 8 cm., placing in a suitable container, and removing the gas by means of a vacuum. The author maintains that determinations of the gaseous phase only do not represent carbon-dioxide production. From data obtained on the solubility of carbon dioxide as $Ca(HCO_3)_2$ at different pressures, the author estimates that when the total carbon dioxide is less than 10 percent and the soil is not particularly dry it

[16] Stoklasa, J. Methoden zur Bestimmung der Atmungsintensität der Bakterien im Boden. *In* Zeit. Landw. Versuch. Oesterr., 14: 1243–1279. 1911.

[17] Lemmerman, O., Aso, K., Fischer, H., and Fresenius, L. Untersuchungen über die Zersetzung der Kohlenstoffverbindungen Verschiedene organischer Substanzen im Boden, Speziele unter dem Einfluss von Kalk. *In* Landw. Jahrb., 41: 217–256. 1911.

[18] Leather, J. W. Soil gases. Mem. Dept. Agr. India., Chem. Ser., 4: 85–132. 1915.

is nearly all in solution. The author found larger quantities of carbon dioxide in the neighborhood of roots of crops than in fallow land.

Russell and Appleyard[19] determined the carbon dioxide content of soil air in samples obtained by simple aspiration through a tube placed about 6 inches below the surface. They found considerable fluctuation in the quantities of carbon dioxide. The variations were attributed principally to seasonal changes. From November to May the temperature and carbon dioxide curves almost coincide, but early in May they diverge and do not come together again until November. Plotting the rainfall for the week preceding date of sampling, a rather close relationship was brought out. The cropped plots showed higher

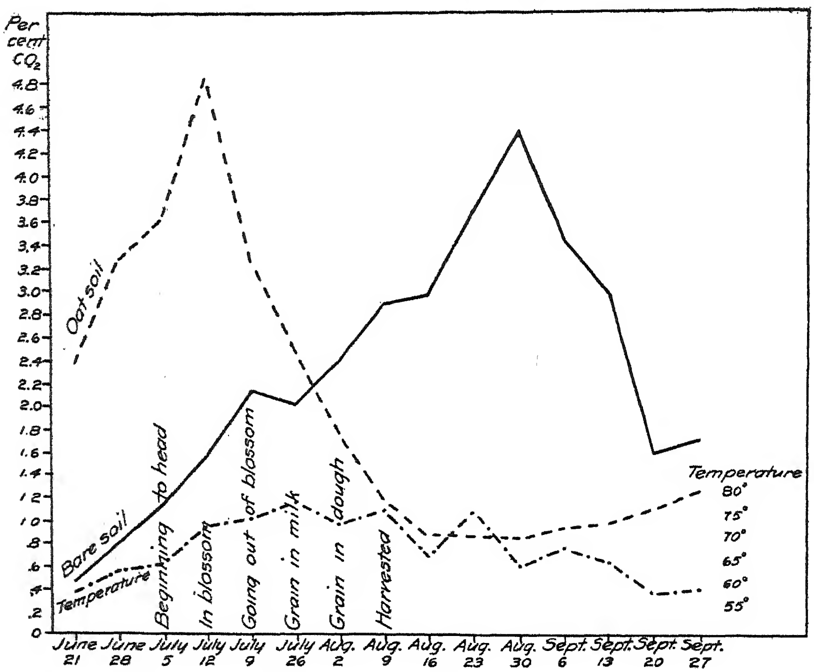


FIG. 13. Diagram showing carbon dioxide in air from unlimed Dunkirk clay loam, cropped and bare, with the mean atmospheric temperature for the week preceding each analysis.

quantities of carbon dioxide than the uncropped, but the authors think this is due to indirect effects. Passing from a neutral to a sour soil there was an increase in carbon dioxide, but different species of plants showed about the same production when grown on the same soil.

[19] Russell, E. J., and Appleyard, A. The atmosphere of the soil; its composition and cause of variation. *In* Jour. Agr. Sci., 7: 1–44. 1915.

These authors,[20] in summarizing the results of three years' work, conclude that the principal factors in carbon-dioxide production in the order of their importance are temperature, moisture, dissolved oxygen, and the growing crop. They obtained increased quantities of carbon dioxide on cropped soil, the two maxima occurring in May and August. The latter was the date of ripening. The authors argue that since little root activity occurs at the ripening period, the production of carbon dioxide can not be referred wholly to respiration. The authors did not find a depressing effect of the crop on carbon-dioxide production. Fred and Hart[21] compared additions of sulfates and phosphates and found in general the latter to be more effective.

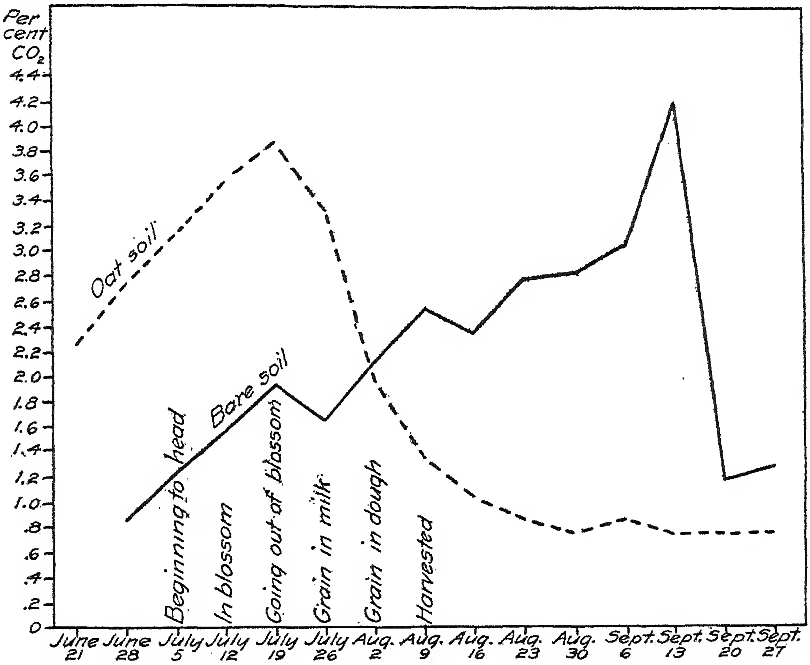


FIG. 14. Diagram showing carbon dioxide in air from limed Dunkirk clay loam, cropped and bare.

Potter and Snyder[22] treated soil with calcium carbonate, sodium nitrate, and ammonium sulfate singly and in combination. The car-

[20] Russell, E J., and Appleyard, A. The influence of soil conditions on the decomposition of organic matter in the soil. *In* Jour. Agr. Sci., 8: 385–417. 1917.

[21] Fred, E. B., and Hart, E. B. The comparative effect of phosphates and sulfates on soil bacteria. Wis. Agr. Expt. Sta. Research Bul. 35. 1915.

[22] Potter, R. S., and Snyder, R. S. Carbon and nitrogen changes in soil variously treated. *In* Soil Sci., 1: 76–94. 1916.

bonate increased the production of carbon dioxide, but the other materials did not. The effect of the calcium carbonate disappeared after 59 days.

The lack of uniformity in the results cited is no doubt due in large measure to the difference in conditions of the experiments and in the methods of determining the amounts of carbon dioxide produced. The evidence in the main points to the conclusion that fairly large quantities of carbon dioxide are excreted by plant roots, that this production reaches a maximum at the period of greatest vital activities, viz, the blooming period, and that it is increased by any factor which increases the vigor of growth of the plant.

Regarding the effect of lime and the reaction of the soil on carbon-dioxide formation, there seems to be little unanimity of opinion. The discrepancy may be due, as Lemmerman points out, to the absorption of the gaseous carbon dioxide when quicklime is applied and to the production of carbon dioxide by purely chemical means when cal-

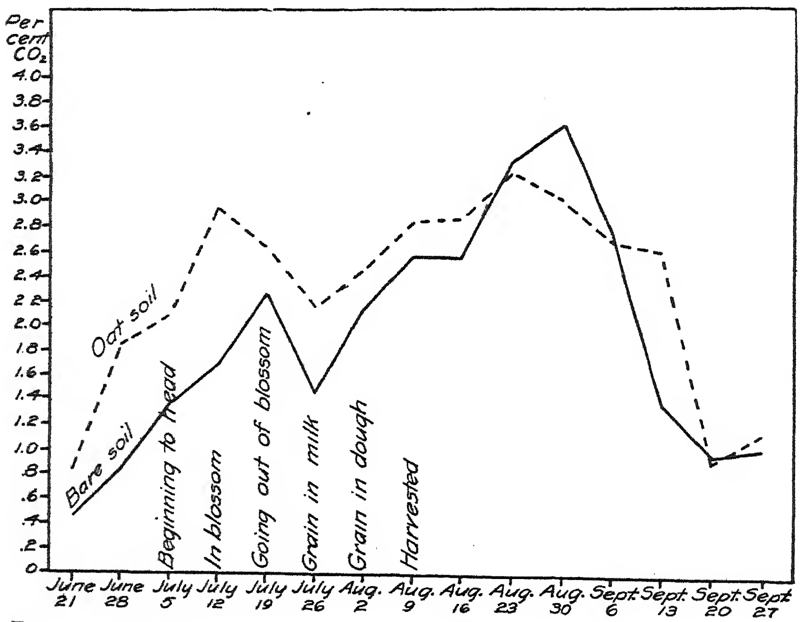


FIG. 15. Diagram showing carbon dioxide in air from unlimed Volusia silt loam, cropped and bare.

cium carbonate is added to acid soils. In either case the determination of carbon dioxide in the soil air by the methods described would not be a measure of carbon-dioxide production. In the experiments

to be described the results merely show fluctuations and not total carbon-dioxide production. These fluctuations were affected by so many uncontrolled factors that they do not necessarily parallel the production curves. However, interpreted in the light of these disturbances, the results show some interesting tendencies.

## Methods.

The samples of air were collected from the drainage tubes at the bottoms of large lysimeter tanks, a description of which has already been published.[23] Each tank is slightly over 4 feet square and 4 feet

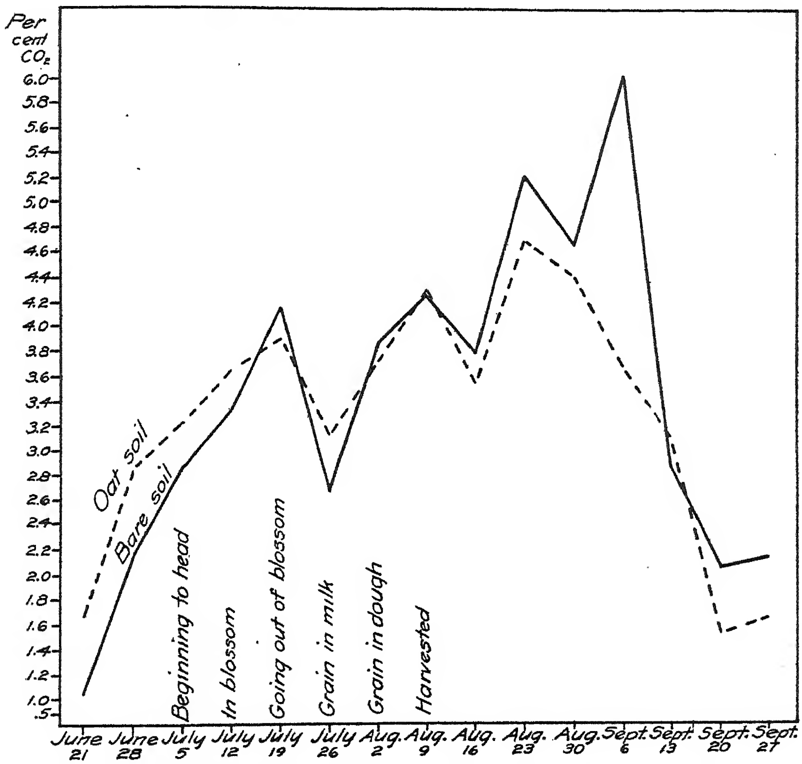


FIG. 16. Diagram showing carbon dioxide in air from limed Volusia silt loam, cropped and bare.

deep, with a capacity of about 3.5 tons of soil. They receive the natural rainfall but no other supply of moisture. Some of these tanks (1–12) were filled with Dunkirk clay loam soil in 1909 and the re-

[23] Lyon, T. L. Tanks for soil investigation at Cornell University. Science, n. s., 29: 621–623. 1909.

mainder with Volusia silt loam in 1910 (tanks 13–16) and in 1913 (tanks 20–21).

In collecting a sample of soil air a calibrated 500-c.c. Ehrlenmeyer flask was fitted with a 2-hole rubber stopper carrying in each hole a Geissler stopcock. One of these stopcocks was connected by means of rubber tubing to a 15-liter aspirator bottle. The other was connected in a similar way to a brass Y-tube and the latter to the drainage tube of the lysimeter. The remaining lower end of the Y-tube was connected to a rubber tube the lower end of which dipped under water. By this means it was possible to aspirate the air from the

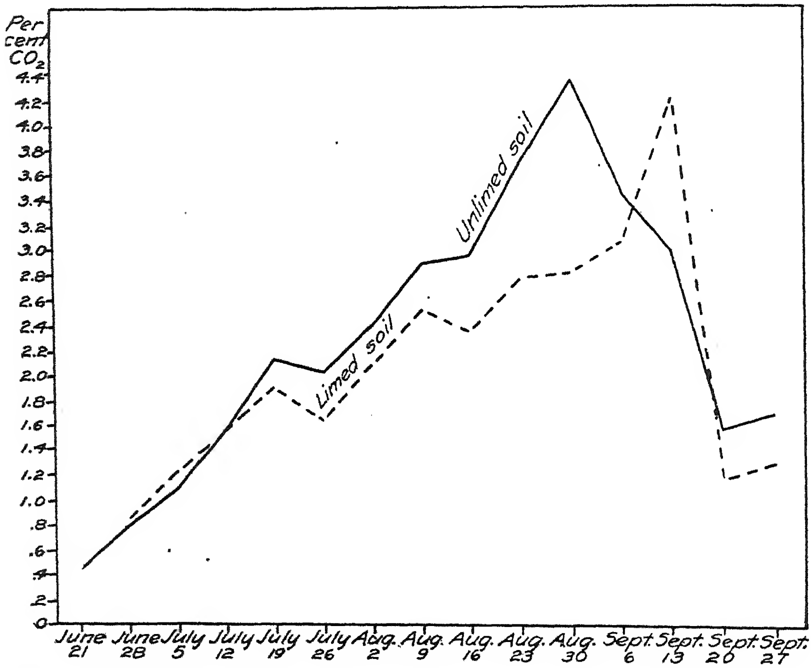


FIG. 17. Diagram showing carbon dioxide in air from uncropped Dunkirk clay loam, limed and unlimed.

lysimeter without interfering with the flow of drainage water. Soil air was drawn through the 500-c.c. calibrated flask until the atmospheric air in the latter was entirely displaced. It was found that emptying the aspirator bottle once was sufficient for this purpose. The flask was then disconnected, taken to the head house adjoining, and allowed to stand for a few minutes until the sample had risen to room temperature. The excess pressure inside the flask was relieved

by opening one of the stopcocks for a moment. Excess of standard barium-hydroxide solution was then added and the flask allowed to stand for 20 minutes with occasional shaking. The excess barium hydroxide was then determined by titration with standard oxalic acid solution.

## Effect of Crop on the Carbon-Dioxide Content of Soil Air.

Determinations of carbon dioxide were made weekly from June 21 to September 27, 1916, in samples of air drawn from tanks 3, 4, 7,

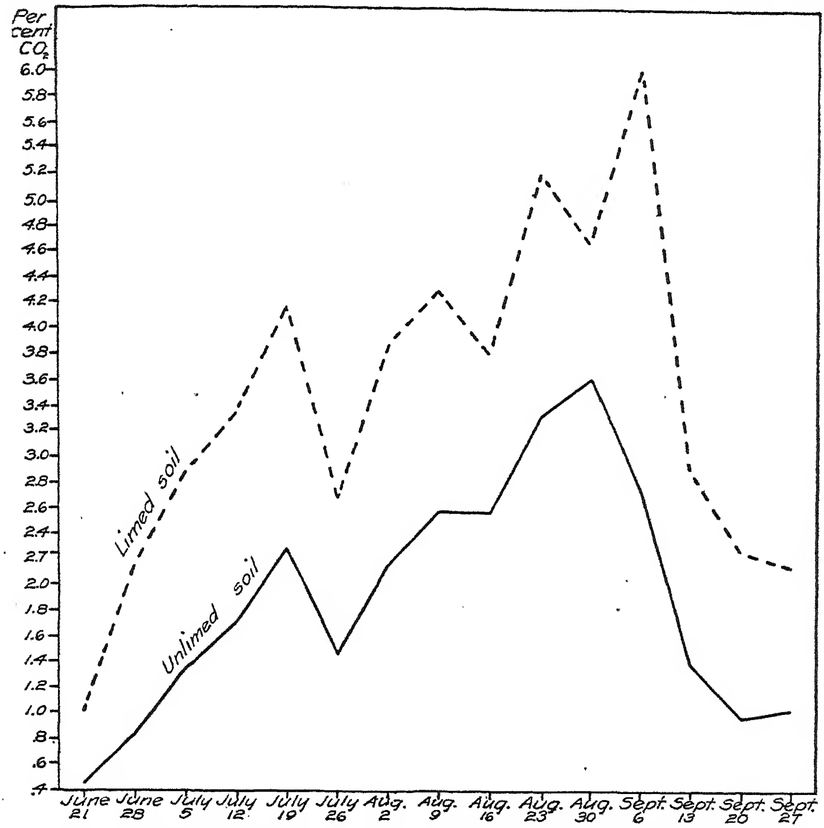


Fig. 18. Diagram showing carbon dioxide in air from uncropped Volusia silt loam, limed and unlimed.

8, 13, 14, 15, and 16, and the results plotted in curves shown in figures 13 to 16, inclusive. Tanks 7 and 8 received applications of 3,000 pounds per acre of quicklime in 1910 and 1915. Tanks 15 and 16 received one application of 3,000 pounds per acre of quicklime in

1913. Tanks 3 and 7 had been previously cropped as follows: 1910, corn; 1911, oats; 1912, wheat; 1913 and 1914, timothy; 1915, corn. Curves 1 and 2 admit of a comparison between Dunkirk clay loam cropped to oats in 1916 (tanks 3 and 7) and the same type of soil which had been kept bare of vegetation since it was put in place in 1909 (tanks 4 and 8). On June 21 the planted and unplanted tanks showed wide differences in the carbon-dioxide content. The cropped tanks showed a rapid increase up to the period of blooming, July 12–19, and then a rapid decline. The bare tanks showed a gradual increase, following in general seasonal variations and not reaching their maxima until August 30 to September 13. The fluctuations in the bare soil may be taken as representing bacterial action. After the maxima were reached there was a rapid decline both in the cropped and uncropped tanks.

As the ordinary diffusion of carbon dioxide from the soil with a lowering of percentage obtains at all times, a fall in the crop curve would result during a period of nonproductivity and hence would not necessarily represent an effect on the bacterial production. In this decline should the cropped soil curve fall considerably below the bare soil curve, the results are to be interpreted as showing some interference with bacterial activity. This is exactly what happened after August 2. On September 13, analyses of the air from the Dunkirk clay loam limed soil showed that the air from the cropped tank contained 0.75 percent carbon dioxide while that from the bare tank gave 4.2 percent. On August 30, the unlimed cropped soil showed a carbon-dioxide content of 0.85 percent, while the bare tank showed 4.3 percent. It may be objected that as the determinations of carbon dioxide represent that in the gaseous phase only and as the cropped soil undoubtedly contained smaller quantities of water, the larger amounts of carbon dioxide found would be due to a relatively smaller quantity in the liquid phase and therefore would not be indicative of relative production. It was not considered advisable to disturb the soil in order to obtain samples for moisture determinations, but there were unquestionably smaller quantities of water in the cropped tanks, as the following figures of the total drainage from these tanks from June 5 to November 1, 1916, show.

| | |
|---|---|
| Tank 3, cropped | 102.4 liters |
| Tank 7, cropped | 94.4 liters |
| Tank 4, bare | 306.0 liters |
| Tank 8, bare | 280.0 liters |

This objection might apply therefore to some extent to the figures

obtained prior to August 2, but on subsequent dates when the cropped tanks showed less carbon dioxide this factor could not have been predominant. In fact, if the smaller percentages subsequent to August 2 were influenced by the amount of moisture the depression due to cropping would be greater than is indicated by the curves.

Figures 15 and 16 permit a similar comparison on Volusia silt loam soil. Tanks 13, 14, 15, and 16 were filled in 1910 and had therefore been in place approximately the same period of years as had the Dunkirk clay loam. Tanks 14 and 16 had been kept bare of vegetation since being filled. Tanks 13 and 15 had been previously cropped as follows: 1913, oats; 1914, Canada field peas; 1915, corn. Comparing the cropped with the uncropped tanks, the curves are almost identical, markedly different from those obtained with the Dunkirk clay loam. It appears that the crop had little effect on the carbon-dioxide con-

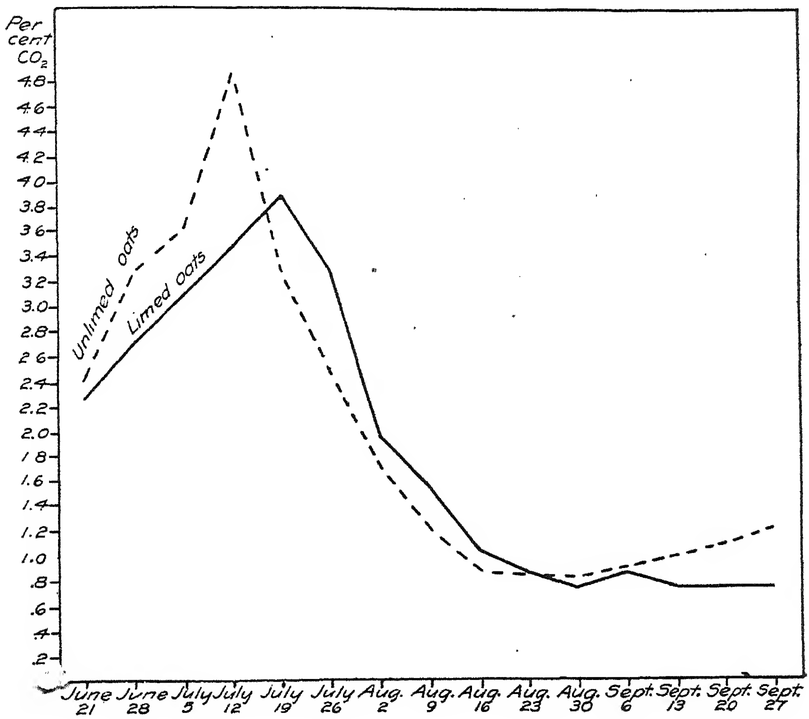


FIG. 19. Diagram showing carbon dioxide in air from cropped Dunkirk clay loam, limed and unlimed.

tent of Volusia silt loam. It is significant that crop growth on the Volusia silt loam was considerably less than on Dunkirk clay loam and it may be that the difference in carbon-dioxide production is in

some way connected with the vegetative activity of the plant. This idea is supported to some extent by the similarity between the curves of the two bare soils.

### Effect of Quicklime on the Carbon Dioxide in Soil Air.

As previously stated, tank 8 received an application of 3,000 pounds per acre of quicklime in 1910 and a similar application in 1915. Tank 16 received 3,000 pounds per acre of quicklime in 1913. It is safe to assume that at the beginning of the season of 1916 all quicklime had been converted into calcium carbonate. The lime requirement (according to the Veitch method) of the surface foot of these soils before being placed in the tanks was approximately 3,000 pounds per acre. The soil in tanks 4 and 14 had never received an application of lime since being placed in the tanks.

Tanks 4 and 8 received 10 tons per acre of manure in 1910 and tanks 14 and 16 had the same quantity in 1913. By reference to figure 17, it appears that liming Dunkirk clay loam had little effect on

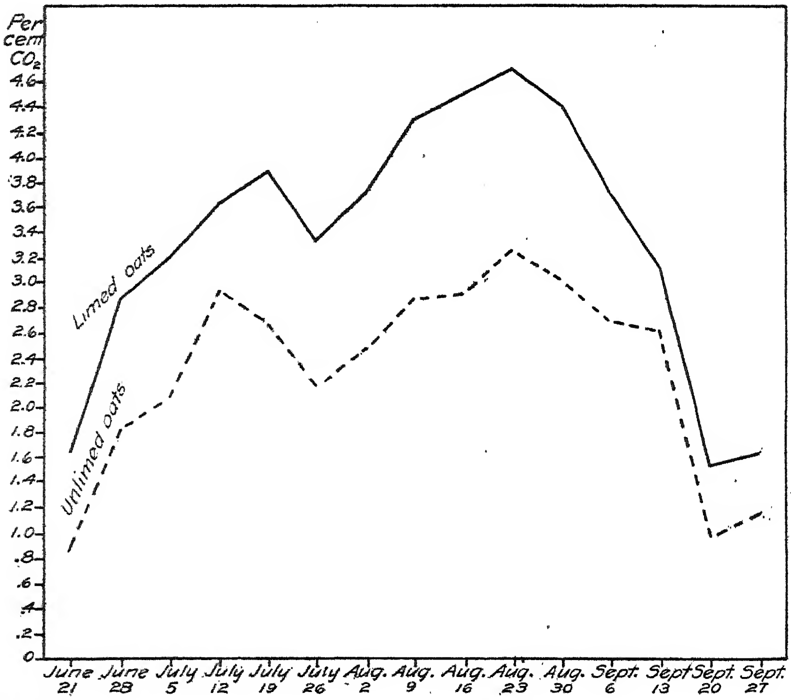


Fig. 20. Diagram showing carbon dioxide in air from cropped Volusia silt loam, limed and unlimed.

the carbon-dioxide content. The figures seem to indicate the usual seasonal fluctuations. The effect of liming on Volusia silt loam is quite marked (fig. 18). The curves for the limed and unlimed soils are approximately parallel at all periods, but the liming apparently had a markedly stimulating effect on bacterial activity. The same general relations are seen when the figures for the cropped tanks limed and unlimed are plotted (figures 19 and 20).

Liming did not increase the carbon dioxide in the air of cropped tanks of the Dunkirk clay loam, but had a decided effect on similarly treated tanks of the Volusia silt loam. It is significant that liming increased crop growth on the latter soil, while it had little effect on the Dunkirk clay loam. Volusia silt loam is a very heavy, compact soil and it is probable that the beneficial effect of line on the carbon-dioxide content is due mainly to an alteration of the physical condition rather than to its effect on the reaction of the soil.

### Effect of Burnt Lime versus Limestone on the Carbon Dioxide of Soil Air.

Tanks 20 and 24 were filled with Volusia silt loam in 1913. On May 1, 1916, tank 20 received an application of 6,000 pounds per acre of quicklime and tank 24 received 12,000 pounds per acre of limestone, ground to pass a 50-mesh sieve. Oats were raised on both

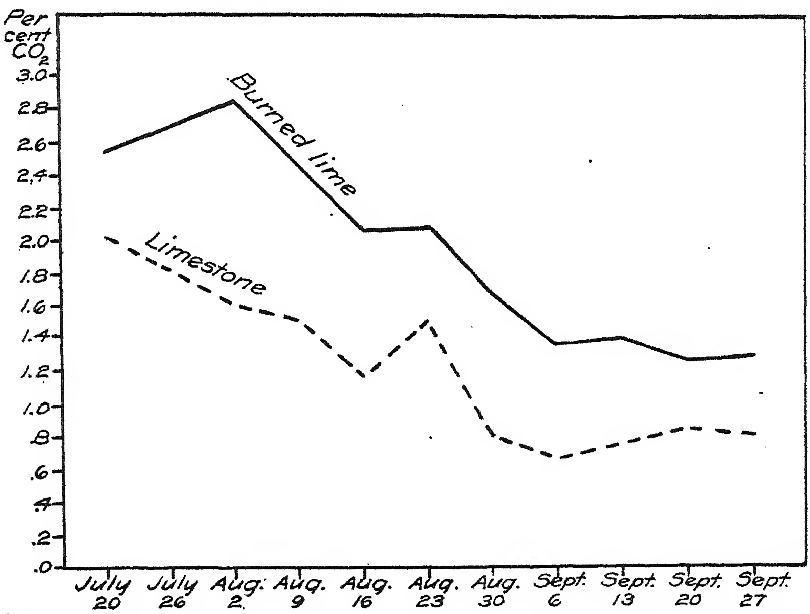


Fig. 21. Diagram showing carbon dioxide in air from cropped Volusia silt loam, limed with burnt lime and with ground limestone.

tanks. Figure 21 shows the results of carbon-dioxide determinations. Burnt lime gave larger quantities of carbon dioxide during the course of the observations (July 20 to September 27, 1916). The burnt lime curve is approximately parallel to the limestone curve. Both curves are similar to the cropping curves already discussed in that there is a decline after the period of greatest activity of the plant. Whether the burnt lime stimulated the bacteria to greater activity or whether the larger amount of carbon dioxide was due to a stimulation of the crop is not evident from the figures. The fact that the burnt lime tank yielded 931 grams of oats as compared with 842 grams from the limestone treatment lends support to the idea that the effect was due to greater crop growth.

## Summary.

1. On Dunkirk clay loam cropping with oats produced striking fluctuations in the carbon-dioxide content of the soil air. The greatest apparent production was at the blooming period. Subsequent to the blooming period there was a marked decrease in the amount of carbon dioxide and this decrease was apparently due to the depressing effect of the crop on production by bacterial action. On Volusia silt loam the crop apparently had little effect on the carbon-dioxide content.

2. On Volusia silt loam addition of quicklime increased the amount of carbon dioxide in the soil air. This effect was noticed both on the cropped and uncropped tanks. On Dunkirk clay loam quicklime apparently produced no effect.

3. Treatment of Volusia silt loam with burnt lime was accompanied by larger production of carbon dioxide than was the treatment with a chemically equivalent quantity of ground limestone.

# WHEAT-BREEDING IDEALS.[1]

HARRY SNYDER.

Wheat is the ideal bread cereal. The physical character of its proteins is such as to impart bread-making qualities, while the nature and variety of the amino acids of these proteins give the maximum food value. Wheat is worthy of the high position assigned it by Sir William Crookes in his presidential address before the British Association for the Advancement of Science in 1898, as "the most sustaining food grain of the great Caucasian race." Any improvement that can be effected in wheat is of the greatest benefit to mankind.

The early history of wheat is shrouded in mystery. Presumably somewhere in Mesopotamia where modern man was nurtured, wheat had its origin. It has been stated that if wheat were not seeded and garnered by man it would soon become extinct, since it cannot exist as a volunteer crop. It would seem that man, in recognizing the great value of wheat as food, had taken in hand its propagation, and that nature had intrusted to him its care since it has lost the power to fend for itself.

Some of the greatest of men have taken a deep interest in wheat improvement. General Washington, while active in the war for independence, had time to think of wheat. In one of his letters he says: "The wheat from some of my plantations by one pair of steelyards will weigh upwards of 60 pounds, and better wheat than I now have I do not expect to make." Referring to this same wheat some years later he wrote: "No wheat that has ever yet fallen under my observation exceeds the wheat which some years ago I cultivated extensively, but which from inattention during my absence of almost nine years from home, has got so mixed or degenerated as scarcely to retain any of its original characteristics properly."

During its thousands of years of domestication, wheat must have undergone some changes in both botanical structure and chemical composition, and it would seem that its development should be continued and that it be still farther improved.

[1] Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917. The author of this paper is chemist for the Russell-Miller Milling Co., Minneapolis, Minn.

Seed selection and production upon rich suitable soils with favorable climatic conditions have heretofore been the chief factors for improving the crop. But other important ways beside seed selection and proper nutrition are now open to us for the improvement of wheat, such as the selection and breeding of the parent wheat stocks. Parenthood in wheat is a factor for either improvement or retrogression, as it is in any life process. I feel too incompetent to attempt to discuss any of the general laws of heredity as they apply to wheat, but I wish to note certain characteristics or properties of wheat, which it would seem should receive more attention in wheat breeding.

It is always desirable to have in mind definite ideas as to what is desired to achieve in plant breeding, but it is particularly so in the case of wheat. The wheat breeder aims to secure new wheats or to improve old strains along one or more of the following lines:

1. Large yield.
2. Stiffness of straw.
3. Resistance to rust and other diseases.
4. Early maturity so as to escape heat, frost, and rust damage.
5. Improved bread-making qualities and higher food value.

The importance of maintaining and improving the quality of wheat deserves particular attention from the wheat breeder. It is not accomplishing enough to secure a new wheat showing a larger yield per acre, if it is at a material sacrifice of the quality of the crop, when it is possible to secure a gain in both yield and quality. As a scholastic proposition, yield and quality might seem antagonistic characteristics, so that you could not expect to secure one without some sacrifice of the other. Happily the work of the late Dr. Saunders in developing the Marquis wheat shows that it is possible to secure both quality and yield as well as early maturity and hardiness. Since it has been proven possible to accomplish such results, I believe more attention should be given to improving the quality of wheat.

Ideas vary as to what is meant by wheat quality, which is a more or less indefinite term difficult to state with mathematical exactness. Quality cannot be expressed in percentage figures of special constituents. It is the bread-maker and the housewife who are the final judges. If the wheat is of such character that the flour milled from it can be made into good bread, then the wheat is of good quality. The miller and the baker can assist in developing latent wheat quality, but they cannot create or impart it when it does not exist. It is much the same as with butter, if it is pleasing in taste and appearance it is of good quality. Neither wheat quality nor butter quality is as yet

capable of being determined absolutely by chemical analysis. Although wheat quality is difficult to measure, certain physical characteristics can be taken as a general index of quality and they will be found helpful to the wheat breeder. For example, a high protein content is very desirable provided the protein is in such forms as to impart the best physical characteristics for bread-making, such as a certain degree of plasticity of the gluten. Hence, quantity and quality of the gluten are a helpful guide to the wheat breeder. Many times, however, the wheat crop is hampered in showing its capabilities as to protein production because of lack of available nitrogen or other plant food. Seasonable variations also sometimes handicap the wheat breeder in arriving at conclusions. Wheat that is of fair glutenous character one year may be starchy another year, and some years the strongest glutenous wheats develop starchy tendencies. While these variations and handicaps are known to exist and must be recognized, certain general principles will be found helpful and can be applied by the wheat breeder.

Suppose the wheat breeder has before him two samples of wheat of similar general character that have been grown and observed under like conditions, and their performance records are quite the same. He wishes to give preference to the one having maximum quality. In one sample, *A*, there are 80 percent of dark amber corneous or glutenous kernels and 20 percent that tend to be light colored and starchy; tests show the glutenous kernels to contain 16 percent protein and the starchy ones 12 percent. In sample *B* there is approximately the same ratio of glutenous and starchy kernels, but the analyses show 14.5 and 11 percent of protein for the two types of kernels. Naturally the preference would be given to the selected kernels of sample *A*, as the type of harder, stronger, and presumably better wheat. The selection, however, should be made not only on the basis of the amount of protein, but due regard should be given also to the physical quality of the gluten. If the gluten from the hard, selected *B* wheat is of the requisite plasticity and of superior quality to that of *A*, then preference should be given to *B*, as a crop from such seed will give the better bread-making value. The rule for selection should be: Get all the protein or gluten you can in the wheat, provided the gluten is of such character as to impart maximum bread-making quality. A high gluten with rather poor bread-making value is a poor combination. To breed wheats with the view of securing the maximum protein without regard to bread-making value is not working along right lines.

In some wheat-breeding work it has been the aim to secure immunity from rust and other diseases. The usual theory is to select as parent stock the most promising wheats as to powers of rust resistance. In some cases a selected durum has been taken as one of the parents. Particular attention must then be given to the other parent, because durum does not impart desirable bread-making qualities. Rust resistance is also obtained indirectly by early maturity. Hence, an early-maturing variety of high quality is more desirable than a later rust-resistant one of poorer quality. It takes time to produce a good wheat by breeding alone, hence more progress will be made when the time element is considered by seed selection from well-established varieties rather than by premature attempts to replace old, well-known types with new and questionable kinds. When a community has established a reputation for producing a wheat of quality the maximum price with a special premium is paid for such wheat. When the wheat is of poor or mediocre quality its marketing is attended with difficulties unless there is a general wheat shortage, when a poor quality commands an abnormal price. This principle of not encouraging the introduction of a poorer wheat where a community has established a reputation for raising the best quality of wheat is recognized by Dr. Saunders in his recommendations in the distribution of his Preston and Marquis wheats.[2]

> Preston, Huron, and Stanley, by careful selection, have been considerably improved; however, they do not produce flour of the highest baking strength, a disadvantage the seriousness of which can easily be exaggerated, but should not be overlooked in those districts where wheat is grown for export, and where a reputation for remarkably high baking strength has already been established. This applies particularly to the central parts of Canada. . . . Taking all points into consideration, Marquis wheat is recommended as the most promising sort at present available for farmers who require a hard, red wheat of high baking strength and ripening earlier than Red Fife.

The production of an inferior quality article in a locality where a reputation has been established for superior goods is more serious than might appear at first consideration. About 1870 the Mohawk Valley of New York produced a superior quality of cheese that commanded a premium in the English markets. A few years later the doctrine of combined cheese and butter production was promulgated. It was argued that the milk could be skimmed a little and the cheese still be just as good, while both cheese and butter could be made and sold. Just about that time the Canadian cheese industry started, and they did not skim, but made cheese only. As a result the Mohawk

[2] Saunders, C. E. *In* Canadian Expt. Farms. Rpt., 1910, p. 171. 1911.

Valley cheese lost its English market, which was won by Canadian full-milk cheese. Following this loss of the cheese market many farms declined in value from $10 to $20 per acre. It is sometimes difficult for an agricultural community to change its procedure and the loss of a good market for a staple product is a serious matter. A reputation for a quality product is a valuable asset for any community. After the war is over, and Kaiser "kultur" is discredited as it deserves, wheat culture will return to normal conditions; wheat will cease to be a war-stimulated industry and it will then become a world-competitive industry where quality will be an important commercial factor.

In the promulgation of new wheats that are lacking in high bread-making qualities but otherwise possess desirable characteristics it is a mistake to argue that the miller is prejudiced against the wheat and that he is not willing to accept it at its face value. The miller, as a rule, is only too glad to get wheat of quality, and he is not liable to be mistaken in his judgment of a new wheat unless he mills and markets only a small quantity of it. A heavy-weight, good-appearing, but poor bread-making wheat may form a small part of a wheat milling blend and not show its poor quality as readily as would be the case if the new wheat alone were milled in quantity. It is a real test of a wheat-breeder's character when he recognizes the defects of a good-looking wheat that proves to be only a mediocre bread-maker. Happily there are such scientists, as the quotation just cited from Dr. Saunders shows.

In testing new varieties of wheat, the small 2-roll sample mill will be found helpful if properly used and attempts are not made to solve milling problems that are not capable of being approached with such meager facilities. A small, so-called experimental mill will enable a sample to be prepared for testing the amount and physical quality of the gluten, and in a general way to tell if the wheat is likely to yield a flour that is reasonably responsive to yeast action. If a wheat passes such a test then it has reached a point where it can be tried in a large way and enough produced for trial in a small but reasonably well-equipped commercial mill. The wheat will finally be measured by regular commercial standards and the sooner a wheat breeder has submitted his new wheat to such a test the better position he is in to judge of the quality of his new product. To attempt to put out a new wheat with insufficient testing as to its quality or to cover up a defect is, to say the least, unscientific, as any shortcomings a wheat may possess are sure to be discovered when put to the test.

The small sample mill cannot be used for determining the flour yield of a wheat or for some of the finer points in connection with flour qualities. There are no short cuts in flour milling, that is, no important operations can be abbreviated or omitted and at the same time a quality flour made. The final test of a wheat must be its deportment under commercial conditions. I do not wish to discourage the use of the sample mill, but to encourage its proper use in wheat breeding.

The bulletins and circulars issued by one of the experiment stations the past year give some interesting data on the comparative workings of the sample or experimental mill and a small commercial mill. Some of the same wheats were milled both experimentally and commercially. Calculations from the published data show that a bushel of the same wheat yielded on the sample mill 5 pounds more flour and 25 percent less feed, with 2 pounds per hundred more of invisible loss than from the commercial mill where the flour was much superior. The sample mill fails to make a proper separation between the feed and the flour. When you check the workings of a small sample or experimental mill against a well-equipped commercial plant many amusing inconsistencies appear that would not be apparent to the layman. Flour milling is a high-grade mechanical industry, and the plant breeder should call upon the miller for expert assistance in this line rather than attempt to become a miller in addition to being a plant breeder. Cooperation upon such questions is the best way to get results.

There are many important side lines or problems which the wheat breeder can take up in connection with his regular work, and which have an important bearing upon the main line he is investigating. The tendency of wheats to become starchy or to develop what is sometimes called yellowberry is one of these problems. While it appears to be due in part to climatic conditions, it is also due to lack of available plant food, particularly nitrogen, as well as to other causes.

For a time some believed that wheats grown on irrigated lands were necessarily starchy in character, but of late years it has been found that wheat of very high quality can be raised by irrigation with proper control of the water supply. The problems of plant food, water supply, and quality of crop are open for further investigation.

Fungous diseases give the wheat breeder additional problems to contend with. The value of formaldehyde as a general fungicide appears to be well known, but many farmers have not as yet been sufficiently impressed with the fact that it is possible to use so strong a

solution as to impair seed germination. During the past year my attention has been called to cases where large losses from overtreatment have resulted. It is not safe to conclude that if a definite strength of formaldehyde solution is good, a larger amount would be better.

National grading will doubtless prove valuable in gradually raising the quality of wheat. When each State and market had different rules for grading, it not infrequently happened that a wheat receiving a No. 2 grade in one market or State would get a No. 1 grade in another, or vice versa. This lack of uniformity has led to serious misunderstanding and trouble. The marketing of clean grain needs to be encouraged. More fanning mills should be used on farms, then less valuable transportation space would be required for marketing the cleaner wheat and the screenings could be fed to live stock on the farms. It never pays to market a dirty product and this applies particularly to wheat. The national grading of grain must necessarily recognize the commercial characteristics of the grains graded, which cannot be based on an imperative academic basis. Any attempt to make it appear that wheat is always wheat and that all weights, kinds, and types are equally valuable for flour and bread-making purposes simply encourages poor, slovenly methods of farming.

The wheat breeder should encourage wheat farmers to produce and disseminate the best varieties of wheat. Seed-wheat farms where high-grade pedigreed wheat is produced are as necessary as stock farms where pedigreed stock is raised. By improving jointly the yield and quality of wheat the wheat breeder renders an important service to mankind. The best of bread-making wheats selected so as to have the maximum protein need little or no supplementing with other more expensive protein-containing foods. The best results are secured from a liberal mixed diet, though good bread that is rich in protein supplies at a minimum cost the maximum of nutrients.

# NATURAL CROSS-POLLINATION IN WHEAT.[1]

H. K. Hayes.

## Introduction.

The pure-line method of breeding has been almost universally adopted for self-fertilized crops. The initial selection is generally considered simply to isolate those types which are present in the commercial variety. Continuous selection in pure lines of self-fertilized crops has not, as a rule, given any improvement of importance, although a few cases are on record of a sudden change in a pure line which proved to be of selection value. Almost all commercial varieties of farm crops are mixtures of various types. Even though all plants are of the same general appearance, selection often isolates types which differ in such important things as yield and resistance to lodging.

As an illustration of the results of such selection, the production of Haynes Bluestem wheat, Minnesota No. 169, may be mentioned. Before the recent introduction of Marquis wheat, this pedigreed type was widely grown in Minnesota. Minnesota No. 169 was one of a large number of selections which were first tested at the Minnesota station in 1892. The initial selection was a single plant which gave progeny of promise and which, when tested in various parts of Minnesota, gave a marked increase as compared with the commercial types then grown.

Minnesota No. 169 is a hairy-chaffed, awnless wheat with red coloring matter in the bran layer of the kernel. An examination in 1915 of bulk seed of this strain showed the presence of some unpigmented or white kernels. These white kernels bred true to the Bluestem type of plant for other characters. Several samples of Minnesota No. 169 as grown by farmers were obtained in 1916 and were examined. Nearly all of these samples contained some white kernels which, when grown, proved to be similar to Haynes Bluestem in other characters.

If Bluestem wheat was originally pure for the red color of the kernel, which seems very likely, the question at once arises as to

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whether the presence of white kernels is due to crossing or to a loss mutation. In either case the breeder is faced with the necessity of purifying the type and one naturally wonders how frequently it will be necessary to repurify a "pure" line.

It seems reasonable to suppose that natural cross-pollination may be a frequent cause of the production of inherited variations within pure lines. If there is much cross-pollination, a careful examination of nursery plots would seem the best possible means for determining the frequency of the occurrence, for under these conditions many different types are being grown at short distances from each other.

## Previous Studies of Natural Cross-Pollination in Wheat.

For a detailed discussion of studies in this field, the reader is referred to a review made by Pope (1915).[2] Some of the more important work along this line may be briefly repeated. Nilsson-Ehle (1915) was able to show by an experimental test that some varieties are much more liable to natural cross-pollination than others.

Only a few cases of cross-pollination have been recorded in North America. In 1903 Saunders (1905) announced a single case of a natural hybrid. Smith (1912) found eight natural hybrids in 96 rows of Turkey winter wheat. More recently, Leighty (1915) has described four cases of natural crosses between wheat and rye, and concludes that the existence of such hybrids indicates that wheat is more often cross-pollinated than was formerly supposed.

## Results at the Minnesota Station.

In 1915, nursery plots of Haynes Bluestem wheat were grown as checks for the purpose of determining the variability of the field used for the nursery work. Plots of 100 plants, placed in the form of a square, were used at this time. The Bluestem plots were placed every fifth plot and at maturity a number of individual plants were selected for the purpose of producing pure lines of Bluestem.

Fifty of these plants were grown in 1916 in individual plots. Of these 50 types, 3 proved definitely that they were natural hybrids and gave ratios which were according to Mendelian expectation; 1 gave 45 brown and 19 white chaffed plants; another gave 32 hairy brown chaff, 16 hairy white chaff, 13 smooth brown chaff, and 5 smooth white chaff plants; the third gave 46 hairy and 19 smooth chaff plants. Two other of the Bluestem selections gave both red and white kernels.

[2] References are to "Literature cited," page 122.

Forty-seven plant selections of Marquis were grown in 1916 from selections made in field variety test plots. Of these all were true for the Marquis type of head, but two gave both red and white kernels. Thirty-four other pure lines were grown from individual plants, no natural hybrids being observed.

In the winter wheat nursery, 54 selections were carefully examined; of these, one proved to be a natural hybrid and gave definite segregation ratios.

Approximately 100 individual plant selections of spring wheat were made in 1916 in the nursery and were grown in 1917. No segregation occurred, although four plants were discovered which were believed to be $F_1$ crosses. It is a comparatively easy matter to tell a first-generation cross between Marquis or Bluestem and any bearded variety of wheat, because the first generation has awns which are intermediate in length.

Thirty-six selections of types which were of promise in 1916 were tested in rod rows in 1917. Two rod rows of each selection were carefully examined to determine any impurities. Of these 36 plots, 21 had from one to eight plants that were clearly first-generation crosses.

## Conclusion.

The results here reported would indicate that conditions in 1915 and 1916 at University Farm were either very favorable for natural crossing in wheat or that its occurrence is much more frequent than has been generally supposed to be the case.

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# NORMAL SELF-FERTILIZATION IN CORN.[1]

H. K. Hayes.

## Introduction.

Methods of breeding self-fertilized plants have been standardized so that at the present time the same general plan is used by nearly all scientific investigators. Many minor points are not yet entirely settled, but these are of relatively little importance. With corn, however, there is little uniformity of opinion among plant breeders as to the actual value of different methods of work. With regard to the correlation of various ear and plant characters and resultant yield of the progeny a large amount of data shows that there is no significant relation. This lack of correlation between ear and plant characters and yield of progeny in corn is partially explained by the fact that environmental effects modify various ear and plant characters to a marked degree. The mode of pollination of the corn plant may be given as a second cause of this lack of relation.

Studies by East (1908, 1909),[2] Shull (1908, 1910), Collins (1910), and others, together with further data, have been reviewed by East and Hayes (1912). One of the conclusions reached as a result of these investigations was that self-fertilization in plants that naturally cross-pollinate reduces vigor and cross-pollination in self-fertilized plants tends to increase vigor. It was believed that this phenomenon of increased vigor in first-generation crosses, which has been called heterosis by Shull, was a physiological stimulus due to heterozygosis, although it was recognized that some factors in the heterozygous condition gave a greater stimulus to development than others. A recent hypothesis of Jones (1917) is very attractive and places the matter on a strictly inheritance basis. He attributes the increased vigor which is often obtained in the heterozygous condition to growth factors. This seems logical, as nearly all experiments show that the heterozygous condition for each particular growth factor gives more than half as great a result as the homozygous condition. While dominance is not complete, there is almost always a tendency to

[1] Published with the approval of the Director as Paper No. 100 of the Journal Series of the Minnesota Agricultural Experiment Station. Received for publication December 16, 1917.

[2] References are to "Literature cited," p. 126.

dominance. The hypothesis of linkage is used to explain why it is impossible to obtain all growth factors in a single homozygous individual.

## EFFECTS OF SELF-FERTILIZATION ON YIELD IN CORN.

Previous investigators have shown that the first year of self-fertilization in corn often causes large reductions in vigor. As a contribution to the question of the actual amount of reduction in yield due to such fertilization the following comparison of the yields of normally pollinated Minnesota No. 13 yellow dent corn and 15 first generation self-fertilized lines is given.

TABLE 1.—*Yield in bushels per acre of normally pollinated Minnesota No. 13 corn and 15 first generation self-fertilized lines.*

| Variety. | Mode of pollination. | Yield, bushels per acre. | Variety. | Mode of pollination. | Yield, bushels per acre |
|---|---|---|---|---|---|
| Minn. 13 | Normal | 49.3 | 13–46 | 1 year selfed | 12.3 |
| 13–9 | 1 year selfed | 15.4 | 13–31 | do. | 25.2 |
| 13–12 | do. | 14.8 | 13–47 | do. | 25.8 |
| 13–17 | do. | 34.2 | 13–56 | do. | 29.4 |
| 13–19 | do. | 18.7 | 13–78 | do. | 28.4 |
| 13–25 | do. | 20.1 | 13–99 | do. | 7.9 |
| 13–30 | do. | 43.1 | 13–199 | do. | 24.3 |
| 13–34 | do. | 19.4 | | | |
| 13–35 | do. | 41.0 | Average selfed lines...... | | 24.0 |

The normally pollinated Minnesota No. 13 gave a yield of 49.3 bushels, while the average of the selfed lines gave a yield of 24.0 bushels. This is slightly more than a 50-percent decrease in yield for the self-fertilized as compared with the normally pollinated seed.

The amount of normal self-fertilization is, therefore, of interest. A preliminary study was outlined at Minnesota and started in 1916 with the purpose of determining the percentage of normal self-pollination under Minnesota conditions.

## PREVIOUS STUDIES.

Waller (1917) has recently reported preliminary results as obtained at the Ohio station. He used yellow and white dent varieties of corn and planted hills of three stalks each of Wing Hundred-Day White in a field of Reid Yellow Dent. The hills of Wing white dent were placed at some distance apart and before pollination two of the three stalks from each hill of the white corn were detasseled. The percentage of white kernels was then determined for each ear of each stalk of the white corn upon which a tassel was allowed to remain. There was found to be considerable difficulty in separating the white

and yellow seeds. An average of 5.13 percent of self-pollination was obtained from these tests.

Results of this nature would be of almost enough value to pay all seedsmen and farmers to use seed from detasseled rows, thus insuring cross-pollination. This method has been encouraged by the Illinois station (Hopkins et al., 1905).

As Waller has pointed out, a number of experiments will need to be made before definite conclusions as to normal self-pollination can be reached.

### Results at the Minnesota Station.

In the Minnesota test, Rustler white dent and Minnesota No. 13 yellow dent were used. Single seeds of Rustler white dent were planted in hills at some distance from each other and a stake was placed beside each white seed. Due to various causes only six ears grown from the white seeds were obtained. The resultant progeny were then carefully examined and a separation was made into three groups, yellows, doubtful yellows, and whites. It was found to be very difficult to separate the seeds, although great care was made to place only those seeds with some yellow color in the endosperm in the yellow group. The result of this classification is given in Table 2.

Table 2.—*Yellow, doubtful yellow, and white seeds obtained from ears of Rustler white dent grown in a field of Minnesota No. 13 yellow dent corn.*

| Ear No. | Yellow. | Doubtful yellow. | White. |
|---|---|---|---|
| 1 | 395 | 22 | 6 |
| 2 | 335 | 20 | 7 |
| 3 | 179 | 23 | 16 |
| 4 | 396 | 35 | 10 |
| 5 | 361 | 101 | 27 |
| 6 | 245 | 28 | 3 |
| Total | 1,911 | 229 | 69 |

The following year a number of hills of the doubtful yellow and white groups were grown and approximately 25 ears from each group were artificially self-fertilized. All of these ears at maturity contained a considerable percentage of yellow seeds, which proves that nearly all seeds were cross-pollinated the previous year.

If the classification had not been tested the whites would have been considered pure white and the doubtful yellow and yellows would have been considered yellow. This shows the impossibility of correctly classifying seeds of crosses between yellow endosperm dent and white endosperm dent varieties of maize without determining the degree of error in the classification.

## Conclusions.

The results here reported appear to justify the following conclusions:

1. The first year of self-fertilization in maize, on the average, causes a reduction of about 50 percent in vigor as determined by the yield in bushels of shelled corn per acre of normally pollinated and self-fertilized strains of Minnesota No. 13 dent corn.

2. If there is normally as high as 5 percent of self-fertilization under field conditions, it might pay seedsmen and corn growers to use seed from detasseled stalks, thus using only cross-pollinated seed.

3. The amount of normal self-pollination under field conditions as determined by a somewhat limited test proved to be certainly less than 5 percent. These results, although too few to base conclusions upon, are here given with the hope that other investigators will make similar tests.

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# MINERAL FOOD REQUIREMENTS OF THE WHEAT PLANT AT DIFFERENT STAGES OF ITS DEVELOPMENT.[1]

A. G. McCall and P. E. Richards.

## Introduction.

Two years ago in a brief paper published in the Journal of this Society[2] the senior author called attention to the desirability of a careful study, under controlled conditions, of the mineral food requirements of the principal farm crops plants at different stages of their development, with a view to working out the fundamentals of a rational fertilizer practice. In this original publication and in a subsequent paper in Soil Science[3] the method of attack of this problem is described. In addition to describing the method, the last-mentioned paper gives the results for the first 24-day growth period for wheat.

In a paper read before the Society for the Promotion of Agricultural Science and printed in the Proceedings of that Society for 1916,[4] the senior author has shown that the ratio of mineral nutrients giving the best growth rate for this early period is practically the same for the soybean as for the wheat plant. During the past year the work has been extended to cover three stages in the development of the wheat plant; namely, the first 30 days, the second 30 days, and finally the period extending from the close of the second 30-day period to the maturity of the plant.

## Method of Experimentation.

The salts employed in making up the nutrient solutions were monopotassium phosphate, calcium nitrate, and magnesium sulfate. Thirty-six different proportions of these salts were used, thus neces-

[1] Contribution from the Department of Soils of the Maryland Agricultural Experiment Station, College Park, Md. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 12, 1917.

[2] McCall, A. G. A new method for the study of plant nutrients in sand cultures. *In* Jour. Amer. Soc. Agron., 7: 249–252. 1915.

[3] McCall, A. G. The physiological balance of nutrient solutions for plants in sand cultures. *In* Soil Science, 2: 207–253. 1916.

[4] McCall, A. G. The physiological requirements of wheat and soybeans growing in sand media. *In* Proc. Soc. Prom. Agr. Sci. for 1916, p. 46–59. 1917.

sitating the growing of 36 different cultures for each of the three growth periods. Since the dry weight was used as a measure of the growth rate during the different periods, it was of course impossible to carry through to maturity the same individuals. According to the plan adopted, the first series of cultures were grown for a period of 30 days, when they were harvested and the dry weights determined. A second series of cultures were then started from the same lot of seed as that used for the first series. During the first 30 days these plants of the second series were given a nutrient solution containing the same proportion of the three salts as had been found to give the best growth rate during the first growth period. From the close of the first 30-day period to the end of 60 days the individual cultures of the second series were supplied with the same different proportions of the three salts as was employed in the first series. At the end of 60 days the second series was harvested and from the dry weights the best proportion of salts for the second period was obtained. In a similar manner the plants for the third series were grown from the same lot of seed and supplied with the best salts proportions during the first and second periods, after which they were given the differential feeding and harvested at maturity.

The growth period for Series I extended from October 10 to November 11, 1916; Series II from December 18, 1916, to February 17, 1917, and Series III from March 14 to June 25, 1917. Plates 2 and 3 show the appearance of the plants at the end of these growth periods. The seed used was northwestern grown spring wheat of the Marquis variety obtained from the Olds Seed Co., Madison, Wis. Spring wheat has proven to be much more satisfactory than winter wheat, since under greenhouse conditions the former develops a stiffer straw and is less difficult to bring to maturity than the latter.

The plants were grown in pure washed quartz sand, the culture pots being arranged on rotating tables, in order to obtain uniformity in external environmental conditions. In the earlier work granite-ware pots were used, but during the past year clay pots have been employed, in order to avoid bringing the nutrient solution into contact with soldered joints. The form of the pot which is now being used and the method of supporting the plants are shown in Plate 3. Figure 22 is a cross-section view of the pot and shows the arrangement of the supply funnel and the outlet tubes.

In order to make the containers impervious to moisture and at the same time prevent the solution from coming into contact with the clay, the pots were first boiled in paraffin to drive the air out of the walls and then brushed over both inside and outside with a thin coat

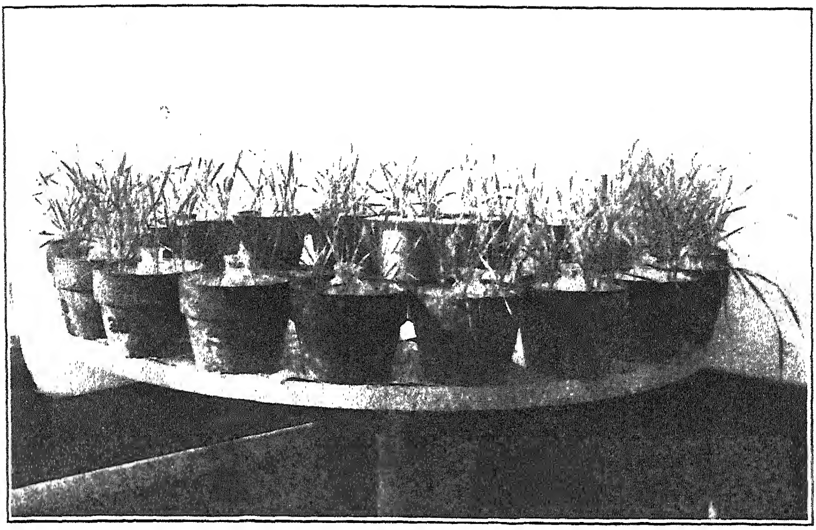
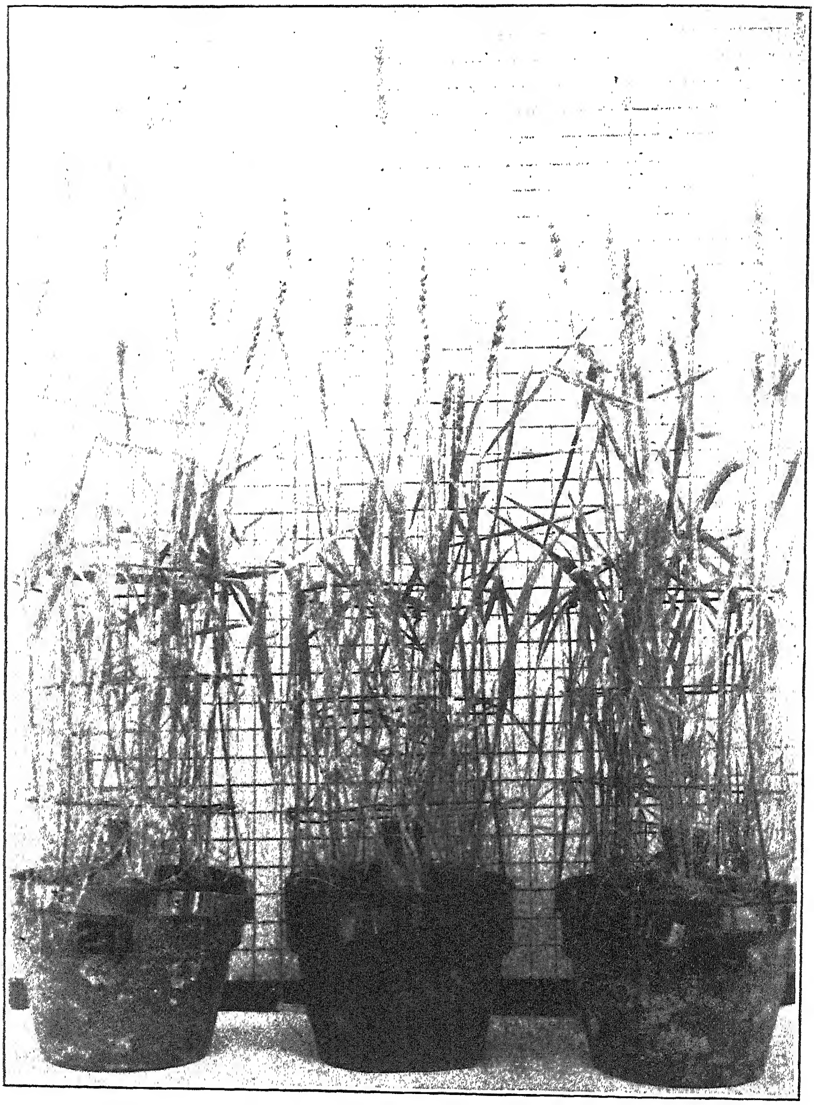


FIG. 1. Rotating table used to secure uniformity in external environment for wheat cultures.

FIG. 2. Wheat plants at the close of the second 30-day period. The plants are supported by an open wire frame which permits the leaves to assume a natural position.



Wheat plants at maturity. The screen at the rear has one-inch mesh.

of hot paraffin. The glass funnel ($D$) rests on an inverted glazed porcelain dish ($F$) which not only supports the funnel but also serves to insure a more thorough distribution of the solution throughout the mass of sand. The glass outlet tube is held in place by a paraffin seal ($B$) and has its inner end resting on the bottom of the pot near the center. The bell-shaped enlargement ($H$) at the end of this tube is closed against the entrance of sand by the insertion of a plug of glass wool. A short length of glass tubing inserted ahead of the wool effectively provides against the possibility of the plug being drawn out when suction is applied for the removal of the solution. The substratum used in these cultures consisted of medium fine white sand which has been washed several times with distilled water from a Barnstead still. The weighed quantity of dry sand was first placed in each pot and then thoroughly washed several times by covering the surface with distilled water and draw- the liquid down through the sand by means of suction applied to the outlet tube. Failure of the control cultures to develop in the sand supplied only with distilled water instead of the nutrient solution was sufficient evidence that the washing was adequate to remove any plant nutrients that might have been present in the unwashed sand. The salts used in making up the culture solutions were Baker's "analyzed" monopotassium phosphate and calcium nitrate and Merck's "blue label" magnesium sulfate. Stock solutions were made up by dissolving gram molecular weights of these salts separately in a liter of water. Before making up the final nutrient solutions the stock solution was diluted to one fourth molecular and stored in flasks which were connected with automatic

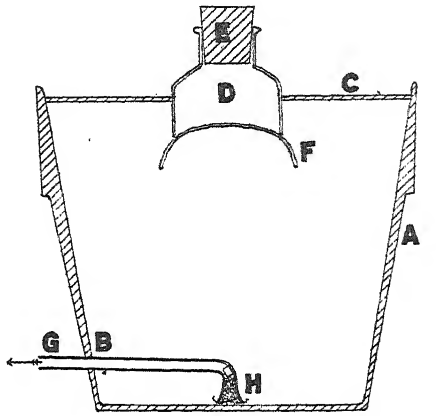



FIG. 22. Cross-section view of the clay pot used for sand cultures. $A$, paraffined clay wall; $B$, paraffin seal; $C$, wax seal covering surface of sand; $D$, supply funnel made by cutting bottom out of a wide-mouthed bottle; $E$, cork stopper; $F$, inverted porcelain dish; $G$, point of attachment to suction line; $H$, inner end of suction tube which is protected against the entrance of sand by means of a plug of glass wool. Note the short length of glass tubing at the bend. This effectively prevents the glass wool from being drawn over when suction is applied.

burettes through which the required amount was drawn each time a new set of nutrient solutions was to be prepared.

In each series 36 cultures were employed, each of which received at the end of each successive 3-day period a culture solution having a total osmotic concentration of 1.75 atmospheres. The solution supplied to each particular culture differed, however, from that supplied to the other cultures in the series, with respect to the proportions of the three component salts. At the end of each 3-day period the pots were weighed and brought back to their original weight by the addition of distilled water. The nutrient solutions were then removed from the pots by suction applied to the outlet tubes and a fresh solution supplied through the inverted funnel at the top, thus insuring an approximately constant total concentration.

## Discussion of Results.

### ARRANGEMENT OF THE CULTURES.

For convenience in designating the individual cultures and to give clearness to the discussion, the cultures have been grouped in the form of an equilateral triangle as has been done for similar series by other writers. These groupings are shown in triangle A of figure 23, in which the individual cultures are represented by circles. It will be seen that the lower row has eight cultures and that as we proceed upward each row has one culture less than the one below, the eighth row containing but a single individual. The employment of the shaded segments to represent the various proportions of the three salts is an adaptation of the scheme employed by Harris[5] in his study of alkali salts. The unshaded segments in each circle represents the number of tenths of the total concentration derived from calcium nitrate, the segments marked by small crosses the number of tenths derived from monopotassium phosphate, and the stippled segments the number of tenths due to magnesium sulfate. Proceeding from the base to the apex of the triangle, the rows are numbered from R1 to R8, while the individual cultures in each row are numbered from left to right. For example, the second culture from the left in the first row is designated R1C2, and similarly the third culture in the sixth row is R6C3. Triangle A of figure 23 shows that all of the solutions supplied to the first row of cultures have approximately one tenth of their total concentration from monopotassium phosphate and those in the second row two tenths, this amount increasing by

[5] Harris, F. S. Effect of alkali salts in soils on the germination and growth of crops. *In* U. S. Dept. Agr., Jour. Agr. Research, 5: 12–27. 1915.

increments of one tenth from row to row until the apex is reached. As indicated by the shading, the first culture at the left in each row has one tenth of its total concentration due to calcium nitrate, this partial concentration increasing uniformly by increments of one tenth until the opposite side of the triangle is reached. In a similar

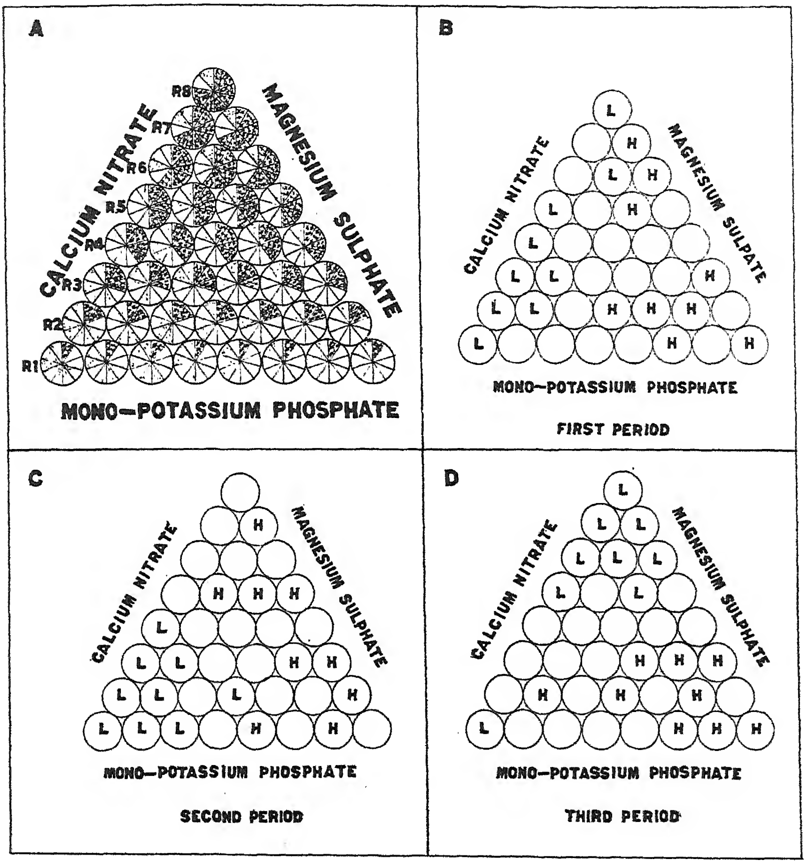



FIG. 23. Triangle *A* shows the salt proportions employed for each culture; and *B*, *C*, and *D* the locations of the best nine and the poorest nine cultures for the first, second, and third growth periods, respectively.

manner the partial concentrations of magnesium sulfate increase from right to left in each row. The circle occupying the position R2C3 has three tenths of its total area unshaded, two tenths marked by crosses and the remaining five tenths stippled, thus indicating that

the solution used for this culture had the proportions of three tenths calcium nitrate, two tenths monopotassium phosphate, and five tenths magnesium sulfate. Throughout the discussion the individual cultures will be designated by the row number and by the position they occupy in the row, using the nomenclature employed by earlier writers.

In order to study better the growth rates, each of the three series of 36 cultures have been divided into three groups, (1) a lower one fourth comprising the 9 cultures giving the lowest yield of tops, (2) an upper one fourth composed of the 9 cultures giving the highest yield, and (3) a medium one half which includes the remaining cultures.

## COMPARISON OF THE RESULTS FOR THE THREE GROWTH PERIODS.

An inspection of the triangular diagrams B, C, and D of figure 23 will facilitate a general comparison of the three sets of cultures representing the three growth periods in the life of the wheat plant. In these diagrams the individual cultures are marked with an *L* if they lie in the low-yield group and with an *H* if they are within the high-yield groups. These groups of cultures will be referred to as the poorest nine and the best nine in the discussion which follows.

From triangle B it will be seen that for the early growth period the solutions which gave the highest yield of tops are characterized by a high calcium nitrate content and a low proportion of magnesium sulfate, while the lowest yield of tops is associated with low calcium nitrate and a high proportion of magnesium sulfate. For this period the effect of the monopotassium phosphate appears to have been almost entirely overshadowed by the other two component salts. A comparison of diagram C, representing the results for the second 30-day period, shows a striking similarity in the location of the areas of high and low yielding cultures, from which it would appear that mineral food requirements of the wheat plant during the second growth period were substantially the same as for the first 30-day period.

From an inspection of triangle D it will be seen that for the third and final growth period the solutions which gave the highest yielding plants are characterized by a relatively high concentration of calcium nitrate and a low proportion not only of magnesium sulfate but also of monopotassium phosphate, while the solutions producing low yields are characterized by a high proportion of monopotassium phosphate, without regard to the ratio of the other two salts. These re-

sults suggest a strong possibility that the acidity of the nutrient solution may be largely responsible for the location of the area of low yielding cultures during the final growth period. The acidity of different nutrient solutions with special reference to the hydrogen in concentration is being made the subject of further investigation.

The mean molecular proportions of the three component salts and the ionic ratios for the culture solutions giving the best and the poorest growth of wheat during the different periods are given in Table I.

TABLE I.—*The mean molecular proportions of the three component salts and the ionic ratios for the culture solutions giving the best and the poorest growth of wheat during the different periods of development.*

| Series and growth rank. | | Mean molecular proportions in tenths of total concentration. | | | Mean cation ratios. | | |
|---|---|---|---|---|---|---|---|
| | | $KH_2PO_4$. | $Ca(NO_3)_2$. | $MgSO_4$. | Mg/Ca. | Mg/K. | Ca/K. |
| Series I, first period. | Best nine..... | 3.4 | 4.7 | 1.9 | 1.08 | 1.50 | 1.98 |
| | Poorest nine.. | 3.8 | 2.0 | 4.2 | 6.55 | 2.80 | 0.49 |
| Series 2, second period | Best nine..... | 3.5 | 4.6 | 1.9 | 1.00 | 1.48 | 1.70 |
| | Poorest nine.. | 2.7 | 1.5 | 5.8 | 8.33 | 5.05 | 0.71 |
| Series 3, third period | Best nine..... | 2.0 | 5.5 | 2.5 | 1.32 | 2.09 | 2.60 |
| | Poorest nine.. | 6.1 | 1.8 | 2.1 | 2.99 | 0.52 | 0.22 |

Table I shows that for the first period the mean molecular proportions of the solutions producing the best nine are 3.4 parts monopotassium phosphate, 4.7 parts calcium nitrate, and 1.9 parts magnesium sulfate, and for the poorest nine, 3.8 parts monopotassium phosphate, 2.0 parts calcium nitrate, and 4.2 parts magnesium sulfate. For the second growth period these proportions remain practically the same, but for the final period the proportions are materially changed, especially for the low yield group. An inspection of ionic ratio values brings out the fact that for the first and second growth periods the culture solutions producing the best growth are characterized by a low ratio of magnesium to calcium, while the solutions giving low yields have a high ratio value of magnesium to calcium. For the final period this wide difference is absent, the ratio of magnesium to calcium having increased slightly for the best nine and decreased very materially for the poorest nine. Attention is also called to the fact that the mean ratio of magnesium to calcium for the best growth for the first and second periods is practically 1 : 1 and for the final period 1 : 1.3. The mean ratio of magnesium to potassium is practically the same for the best nine for the first and second growth periods, and as in the case of the magnesium-calcium ratio, there is

a slight increase for the final period, thus indicating an increase in the physiological requirement for magnesium during the late stages in the development of the wheat plant.

Further discussion of these data is being reserved until the conclusion of similar studies of the mineral food requirements of the soybean plant and of buckwheat, which are now being conducted by the Department of Soils of the Maryland experiment station.

## RELATION OF SIZE OF SAMPLE TO KERNEL-PERCENTAGE DETERMINATIONS IN OATS.[1]

R. J. Garber and A. C. Arny.

In carrying out the rotation investigation and the varietal test work at University Farm, the farm crops section of the Minnesota station has occasion each year to make a considerable number of determinations of percentage of kernel in oats (a) of the same variety grown in different rotations and (b) of a number of varieties grown under similar soil conditions. For oat varieties, these data are of interest as a basis for comparing true yielding ability and feeding value. Inasmuch as hulling oats by hand is rather expensive, it is highly desirable to minimize the work so far as is compatible with accuracy. The data collected in seeking a solution to this problem are presented herein.

Love (1912)[2] determined for two crops of oats the bushel weight, the weight per 100 grains, and the percentage of kernel for each of a large number of varieties. The weight per 100 grains was obtained by weighing several composite lots of from 50 to 100 grains and averaging these for each variety. Kernel percentage determinations were made from the weighed samples. Love found a difference of nearly 100 percent in the weight per 100 grains as determined for the different varieties. Comparing the weight per 100 grains within any variety for the 2-year period, the variation was not great. He found a considerable variation in percentage of kernel for the different varieties, but no variety showed a wide variation for the 2-year

[1] Published with the approval of the Director as Paper No. 104 of the Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, Minn. Received for publication December 26, 1917.

[2] Dates in parenthesis refer to "Literature cited," p. 142.

period. No correlation was found between weight per hundred grains and percentage of kernels or between weight per bushel and percentage of kernel.

Surface and Zinn (1916) give data showing no relation between weight of a thousand grains and percentage of hull.

The thirteen varieties studied in this investigation (Table 1) were

TABLE 1.—*Weight of 1,000 grains and mean percentage of kernel in 13 varieties of oats with the standard deviation and coefficient of variability in twenty 50-grain samples of each variety.*

| Variety. | Group. | Weight of 1000 grains. | Means. | Standard deviations. | Coefficients of variability. |
|---|---|---|---|---|---|
| Swedish Select..... | Sativa | 29.090 | 72.19±.14 | .9500±.10 | 1.32±.14 |
| Silvermine.......... | do | 23.500 | 71.73±.13 | .8599±.09 | 1.20±.13 |
| Victory ........... | do | 25.415 | 72.56±.18 | 1.1795±.13 | 1.63±.17 |
| Banner............. | do | 25.990 | 71.92±.12 | .7901±.08 | 1.10±.12 |
| Improved Ligowa .. | do | 23.505 | 72.55±.17 | 1.1146±.12 | 1.54±.16 |
| Sixty Day......... | do | 18.645 | 72.23±.14 | .9202±.10 | 1.27±.14 |
| Iowa No. 103...... | do | 19.525 | 72.39±.19 | 1.2851±.14 | 1.78±.19 |
| White Tartar...... | Sativa orientalis | 26.620 | 74.05±.10 | .6601±.07 | .89±.09 |
| Black Tartarian.... | do | 20.410 | 69.75±.15 | .9641±.10 | 1.38±.15 |
| Storm King........ | do | 45.455 | 62.16±.18 | 1.2248±.13 | 1.97±.21 |
| Garton No. 748 .... | do | 21.220 | 76.70±.12 | .7924±.08 | 1.03±.11 |
| Red Rustproof..... | Sterilis | 33.220 | 72.80±.11 | .7055±.08 | .97±.10 |
| Burt.............. | do | 24.095 | 73.26±.13 | .8675±.09 | 1.18±.13 |

grown on University Farm in 1917 and all but the five last named, which grew on the plots devoted to classification work, appeared in the regular varietal tests. The oats taken from these two sources were thrashed similarly, so their respective percentages of kernel are directly comparable. It was thought advisable to select varieties differing as widely as possible in size and shape of grain, in percentage of kernel, and in other characteristics. By so doing, a range of 62.16 to 76.70 in percentage of kernel was obtained, which was greater than would ordinarily be found in any one variety over a period of years and consequently obviated the necessity of using the crop from more than one year.

The method employed in making the kernel determinations was as follow: A composite sample of a pound or more was made up for each variety by taking portions from various places within the bags containing the bulk oats. These composite samples were taken to the laboratory and each thoroughly mixed. Then, as desired, a composite sample was poured into a conical pile, from one side of which the samples used in determining the kernel percentages were taken. The grains were counted out just as they came and, with the exception of broken or diseased ones, which were rejected, no selection

whatever was made. The twenty 50-kernel samples of each variety were collected at one time and numbered consecutively from 1 to 20. Number rather than weight of grains was chosen as a basis for sampling because the former was more convenient. The average weight of any sample used may readily be ascertained from the weight of 1,000 grains for the same variety, as given in Table 1. Table 2 shows the frequency distributions of kernel percentages in the different varieties.

TABLE 2.—*Frequency distributions of kernel percentages of 13 varieties of oats, as shown by determinations of twenty 50-grain samples of each variety.*

| Classes. | Swedish Select. | Silvermine. | Victory. | Banner. | Imp. Ligowo. | Sixty-Day. | Iowa No. 103. | White Tartar. | Black Tartarian. | Storm King. | Garton No. 748. | Red Rust-proof. | Burt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60.25 | | | | | | | | | | 3 | | | |
| 60.75 | | | | | | | | | | 1 | | | |
| 61.25 | | | | | | | | | | 2 | | | |
| 61.75 | | | | | | | | | | 3 | | | |
| 62.25 | | | | | | | | | | 2 | | | |
| 62.75 | | | | | | | | | | 2 | | | |
| 63.25 | | | | | | | | | | 3 | | | |
| 63.75 | | | | | | | | | | 3 | | | |
| 64.25 | | | | | | | | | | 1 | | | |
| * * * | | | | | | | | | | | | | |
| 67.75 | | | | | | | | | 1 | | | | |
| 68.25 | | | | | | | | | 1 | | | | |
| 68.75 | | | | | | | | | 2 | | | | |
| 69.25 | | | | | | | 1 | | 3 | | | | |
| 69.75 | | 1 | 1 | | | | | | 7 | | | | |
| 70.25 | 1 | 1 | | 1 | 2 | | 1 | | 1 | | | | |
| 70.75 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | | 3 | | | | |
| 71.25 | 2 | 2 | | 4 | | 4 | 1 | | 1 | | | 1 | 1 |
| 71.75 | 2 | 7 | 3 | 6 | 3 | 1 | 3 | | 1 | | | 2 | 1 |
| 72.25 | 3 | 5 | 3 | 2 | 1 | 5 | 2 | | | | | 3 | 2 |
| 72.75 | 5 | 1 | 6 | 4 | 6 | 5 | 4 | 1 | | | | 5 | 4 |
| 73.25 | 4 | | 3 | 2 | 2 | | 4 | 3 | | | | 5 | 2 |
| 73.75 | 1 | 1 | 1 | | 4 | 3 | 1 | 4 | | | | 4 | 5 |
| 74.25 | | | | | | | 2 | 7 | | | | | 5 |
| 74.75 | | | 1 | | 1 | | | 2 | | | | | |
| 75.25 | | | 1 | | | | | 3 | | | 2 | | |
| 75.75 | | | | | | | | | | | 1 | | |
| 76.25 | | | | | | | | | | | 4 | | |
| 76.75 | | | | | | | | | | | 5 | | |
| 77.25 | | | | | | | | | | | 4 | | |
| 77.75 | | | | | | | | | | | 4 | | |

Double oats, commonly so called where the lemma of the primary grain completely or almost completely envelops the secondary grain, were counted as one. This accounts for the seemingly high weight of 1,000 grains of the Storm King variety.

The weighings of the samples before hulling and of the kernels afterward were made in grams to three decimal places on a Troem-

ner enclosed balance. The kernels were carefully removed by hand.[3] In order to insure more accuracy only one person worked on the seeds of each variety.

After the data were collected and the various kernel percentages calculated, tables of the same form as Table 3, which is presented as a representative one, were prepared for each variety. All the varieties were handled exactly alike, so an explanation of one table will suffice. The column headed "Number of samples" gives the number of frequencies involved in determining the statistical constants for the various replications. Here an explanation in regard to how the replications were made is necessary. As has been stated. the 20 50-kernel samples were numbered from 1 to 20. To secure 1 replication the mean percentages were calculated for samples 1 and 11, 2 and 12, 3 and 13, etc., until the entire 20 were used to make up the resultant 10 mean percentages. For 2 replications, samples 1, 7 and 13; 2, 8 and 14, etc.; for 3 replications, samples 1, 6, 11 and 16; 2, 7, 12 and 17, etc.; for 4 replications, samples 1, 5, 9, 13 and 17, etc.; for 5 replications, samples 1, 4, 7, 10, 13 and 16, etc.; for 9 replications, samples 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19, etc., were similarly combined and the means determined. Each mean so obtained represents one of the percentage frequencies for that particular replication. Thus, where one replication is made, 10 percentage frequencies each representing 100 oat grains result; where two replications are made, 6 percentage frequencies each representing 150 grains result; and so on for the various replications. The first horizontal column of Table 3 gives the constants where single 50-grain samples only were

TABLE 3.—*Variability of percentage of kernel in Swedish Select oats.*

| Replications. | No. of kernels in each sample. | No. of samples. | Means. | Standard deviations. | Coefficients of variability. |
|---|---|---|---|---|---|
| None | 50 | 20 | 72.19 ± .14 | .9500 ± .10 | 1.32 ± .14 |
| One | 100 | 10 | 72.19 ± .10 | .4805 ± .07 | .67 ± .10 |
| Two | 150 | 6 | 72.25 ± .11 | .3942 ± .08 | .55 ± .11 |
| Three | 200 | 5 | 72.19 ± .09 | .2946 ± .06 | .41 ± .09 |
| Four | 250 | 4 | 72.19 ± .09 | .2800 ± .07 | .39 ± .09 |
| Five | 300 | 3 | 72.25 ± .08 | .2086 ± .06 | .29 ± .08 |
| Nine | 500 | 2 | 72.20 ± .04 | .0852 ± .03 | .12 ± .04 |

considered. Table 1 presents this data for the several varieties studied, together with the weight of 1,000 grains of each variety.

Considering the standard deviations as given in Table 3, it is apparent that a 50-grain sample with a constant of .9500 ± .10 gave a

[3] The hulling was done by two student assistants, B. A. Holt and G. R. Kokatnur, and the senior author.

less accurate determination than a 100-grain sample with a constant of .4805 ± .07. The standard deviation of the former is almost double that of the latter. Between 100-grain and 150-grain samples there is much less difference, but still some decrease in the standard deviation. Relatively the same decrease is shown in going from the 150-grain to the 200-grain samples. Increasing the sample to 250 grains gave a standard deviation of .2800 ± .07, which is not a marked reduction. However, the use of 300-grain and 500-grain samples gave standard deviations of .2086 ± .06 and .0852 ± .03 respectively, which are more decided reductions. The difference between this constant, where one replication representing 100-grain samples and nine replications representing 500-grain samples were used, is .3953 ± .08, which is more than four times its probable error and consequently has some statistical significance. The foregoing observations are likewise brought out by considering the coefficients of variability. In general, similar tables worked up for each of the other twelve varieties gave results concordant with those of Table 1, but there was not always the same comparatively uniform diminishment in standard deviations and coefficients of variability. This is well shown in Table 4.

It will be noted from Table 3 that the means of the different replications vary but slightly, the actual difference between the two extremes being but 0.06 percent. This, in general, held true for all the varieties. In most cases the difference between the extremes was less than 0.05 percent and in no instance was it greater than 0.12 percent. Uniformity of the means within each variety establishes a close correspondence between standard deviations and the related coefficients of variability, except that the latter are numerically greater. The relatively high value of the means compared with their absolute differences within any one variety also serve to make the two indices of variation for any one replication closely reciprocal. In view of these facts, Table 4 includes only the coefficients of variability rather than both the coefficients and the standard deviations, which would be largely a duplication.

Table 4 gives all the coefficients of variability for the twenty 50-grain samples and the different replications for each of the thirteen varieties, together with the statistical constants of these coefficients. Consider the column headed single 50-grain samples. Here the coefficients of variability of each of the 50-grain samples is given opposite the variety from which the determination was made. It is interesting to note in this connection that in no case does the coefficient

TABLE 4.—*Coefficients of variability for the twenty 50-grain samples and the different replications for each of the 13 varieties studied, together with the statistical constants of these coefficients.*

| Varieties. | Number of replications. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Single sample. | One. | Two. | Three. | Four. | Five. | Nine. |
| Swedish Select | 1.32±.14 | .67±.10 | .55±.11 | .41±.09 | .39±.09 | .29±.08 | .12±.04 |
| Silvermine | 1.20±.13 | .60±.09 | .75±.15 | .33±.07 | .43±.10 | .34±.09 | .03±.01 |
| Victory | 1.63±.17 | 1.26±.19 | .84±.16 | .63±.13 | .76±.18 | .14±.04 | .57±.19 |
| Banner | 1.10±.12 | .77±.12 | .68±.13 | .27±.06 | .41±.10 | .55±.15 | .05±.02 |
| Improved Ligowa | 1.54±.16 | 1.05±.16 | .49±.10 | .68±.15 | .38±.09 | .13±.04 | .36±.12 |
| Sixty Day | 1.27±.14 | .79±.12 | .72±.14 | .57±.12 | .48±.11 | .14±.04 | .08±.03 |
| Iowa 103 | 1.78±.19 | 1.25±.19 | .72±.14 | .69±.15 | .85±.20 | .62±.17 | .30±.10 |
| White Tartar | .89±.09 | .57±.09 | .63±.12 | .44±.09 | .13±.03 | .22±.06 | .13±.04 |
| Black Tartarian | 1.38±.15 | .46±.07 | .65±.13 | .29±.06 | .79±.19 | .43±.12 | .30±.10 |
| Storm King | 1.97±.21 | 1.17±.18 | .90±.18 | .78±.17 | .76±.19 | .55±.15 | .31±.10 |
| Garton 748 | 1.03±.11 | .47±.07 | .49±.10 | .38±.08 | .21±.05 | .43±.12 | .18±.06 |
| Red Rustproof | .97±.10 | .58±.09 | .54±.11 | .33±.07 | .37±.09 | .19±.05 | .21±.07 |
| Burt | 1.18±.13 | .84±.13 | .71±.14 | .71±.15 | .39±.09 | .75±.21 | .05±.02 |
| *Statistical constants of the coefficients of variability for the 13 varieties.* | | | | | | | |
| Means | 1.33±.06 | .81±.05 | .67±.02 | .50±.03 | .49±.04 | .37±.04 | .21±.03 |
| Standard deviations | .3111±.04 | .2771±.04 | .1217±.02 | .1741±.02 | .2202±.03 | .1970±.03 | .1503±.02 |
| Mean coefficient of variability | 23.39±3.26 | 34.21±5.03 | 18.15±2.48 | 34.82±5.13 | 44.94±7.04 | 53.24±8.82 | 71.57±13.47 |

exceed 2 percent. The mean of the coefficients appears near the bottom of the column. The standard deviation and the coefficient of variability immediately following were obtained in the usual way. In other words, each set of statistical constants near the bottom of Table 4 was computed from thirteen variants each of which is an index of variation for a definite number of samples composed of a definite number of grains.

Considering the table from the standpoint of varieties, it is found that they differ widely in degree of variability. For instance, the variety of Storm King, with its comparatively high percentage of hull, has a coefficient of variability of $1.97 \pm .21$, which is about twice as much as that for Red Rustproof, $.97 \pm .10$. This relationship is maintained fairly consistently throughout the various replications. By comparing these two extremes, it becomes evident that to secure the same accuracy in determining the percentage of kernel, Storm King requires a larger sample than Red Rustproof. Some varieties, as Black Tartarian, show considerable fluctuation and lack of consistency for the various replications. This undoubtedly is due to the somewhat small number of variants involved. In general, however, the varieties tend to corroborate each other.

Comparing the coefficients of variability in the first and second columns, it is shown at a glance that one replication representing 100-grain samples give much less variability than single 50-grain samples. In nine out of thirteen cases the coefficients for one replication is greater than for two replications, as is shown by comparing columns two and three. Two replications except in two instances give higher coefficients than three replications. Between 200-grain and 250-grain samples represented by 3 and 4 replications, respectively, there is little difference in the coefficients. On the average, 500 grains constitute a somewhat more representative sample for the determination of percentage of kernel than 300 grains.

Examine next the statistical constants of the coefficients of variability. The mean of each column is not presented as an expression of variability for the thirteen varieties considered as one group of variates, but rather as the average of the coefficients of variability for the thirteen varieties, each of which constitutes a group of variates. The highest mean is found for the single 50-grain samples and the lowest for the 500-grain samples. The former also has the highest standard deviation, but the latter has the highest coefficient of variability. Where two replications are made, the standard deviation of the coefficients, $.1217 \pm .02$, is the lowest. In comparing the means of the coefficients for columns 1 and 2, again a decided advantage is

found in favor of using one replication rather than single 50-grain samples. While the mean of the coefficients in column 3, .67 ± .02, is somewhat lower than that of column 2, .81 ± .05, the difference, .14 ± .05, is not quite three times its probable error. The difference between the means of the coefficients in columns three and four is .17 ± .04. Three replications or 200-grain samples diminish the mean of the coefficients for one replication or 100-grain samples by .31 ± .06, which is five times its probable error and therefore significant. The comparatively low variability of the 200-grain samples is another point in their favor. The difference between the means, .01 ± .05, of three and four replications certainly has no statistical value. The differences between the means of four and five replications and of five and nine replications are .12 ± .06 and .16 ± .05, which are two and slightly more than three times their respective probable errors. Between the means of the coefficients of single 50-grain samples and three replications the difference is .83 ± .07, while between the three and nine replications the difference is only .29 ± .04. In other words, 150 grains added to a 50-grain sample reduces the average variability almost three times as much as 300 grains added to a 200-grain sample. Although it is evident from the above data that the 500-grain sample is the most accurate, it is for the individual to determine whether for his purpose it is sufficiently more accurate than the 200-grain sample to justify the additional work incidental to hulling the larger quantity of oats.

In order to examine still further what constituted a desirable sample of oats for determining the percentage of kernel, 100 samples of 50 grains each of Improved Ligowa, which is of a Swedsih Select type, were counted out, the kernel percentage determinations made, and the replications followed in the same systematic way as in the several varieties. The results are tabulated in Table 5. The fre-

TABLE 5.—*Variability in percentage of kernel of Ligowa oats.*

| Replications. | No. of kernels in each sample. | No. of samples | Means. | Standard deviations. | Coefficients of variability. |
|---|---|---|---|---|---|
| None | 50 | 100 | 72 71 ± .07 | 1.0638 ± .05 | 1.46 ± .07 |
| One | 100 | 50 | 72.71 ± .08 | .7915 ± .05 | 1.09 ± .07 |
| Two | 150 | 33 | 72.70 ± .06 | .5161 ± .04 | .71 ± .06 |
| Three | 200 | 25 | 72.71 ± .07 | .5430 ± .05 | .75 ± .07 |
| Four | 250 | 20 | 72.71 ± .08 | .5113 ± .05 | .70 ± .07 |
| Five | 300 | 16 | 72.68 ± .06 | .3545 ± .04 | .49 ± .06 |
| Nine | 500 | 10 | 72.71 ± .08 | .3774 ± .06 | .52 ± .08 |

quency distribution of these 100 samples was as follows: 70.25, 5; 70.75, 5; 71.25, 2; 71.75, 15; 72.25, 9; 72.75, 18; 73.25, 18; 73.75, 19; 74.25, 7; and 74.75, 2.

One replication reduces the coefficient of variability of single 50-grain samples by $.37 \pm .10$ and two replications further reduce the coefficient by $.38 \pm .09$, thus making a difference between 50-grain and 150-grain samples of $.75 \pm .09$, which is approximately eight times its probable error and, therefore, of statistical value. Considering replications two, three, and four, no difference of statistical significance appears; likewise, between five and nine replications. The difference between four and five replications is only $.21 \pm .10$, while between five and nine replications, it is negligible.

In view of the foregoing facts a 150-grain sample of Improved Ligowa oats taken as described gave as statistically representative a sample as a 200-grain or a 500-grain sample. These results with the large number of grains of a single variety are in substantial agreement with the interpretation of the data as given for the thirteen varieties.

## Conclusions.

From the data presented in this study, the following conclusions may be drawn:

1. In general, a 200-grain sample taken as has been described gives a sufficiently accurate determination of percentage of kernel in oats for all ordinary purposes. The weight of this size of sample varies from 3 grams in early to 5 grams in midseason and late varieties in Minnesota.

2. Where more than ordinary accuracy is necessary, the sample should be increased to at least 300 grains, and with some varieties still larger samples are desirable.

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# AGRONOMIC AFFAIRS.

## MEMBERSHIP CHANGES.

The membership reported in the January issue was 656. Since that time 16 new members have been added, 3 have resigned, 1 has died, and 30 have lapsed for nonpayment of dues of 1916, a net loss of 18 and a present membership of 638. The names and addresses of the new members, names of those lapsed, deceased, and resigned, and such changes of address as have been noted since the last issue, are as follows:

### New Members.

ANDERSON, ARTHUR, Univ. Farm, Dept. of Agronomy, Lincoln, Neb.
BARBEE, O. E., Cliff House, Pullman, Wash.
BERRY, ROGER E., 404 Knoblock St., Stillwater, Okla.
GORDON, THOMAS B., Mass. Agric. College, Amherst, Mass.
HASELTINE, L. E., 2301 Durant Ave., Berkeley, Calif.
HATCHER, OTTO, 318 West St., Stillwater, Okla.
HILDEBRAND, E. B., 112 N. Main St., Stillwater, Okla.
JOHNSON, D. R., 220 Knoblock St., Stillwater, Okla.
JOHNSON, GEORGE F., 256 W. Woodruff Ave., Columbus, O.
KEARNEY, T. H., Bureau of Plant Industry, Washington, D. C.
McDOWELL, C. H., Supt. Substation No. 6, Denton, Texas.
McGUFFEY, C. CARL, McGuffey, Ohio.
THOMPSON, R. S., Highland, Calif.
TURNER, A. F., K. S. A. C., Manhattan, Kans.
WELLS, W. G., Bur. Plant Ind., U. S. D. A., Washington, D. C.
WUNSCH, W. A., Acting Co. Agt., Newton, Kans.
ZINN, JACOB, Agric. Experiment Station, Orono, Me.

### Members Resigned.

EDWARDS, R. W., KYLE, C. H., WORTHEN, E. L.

### Members Lapsed.

L. J. BRIGGS.
I. N. CHAPMAN.
ERNEST W. CURTIS.
N. C. DONALDSON.
F. V. EMERSON.
RAYMOND C. GAUCH.
E. W. HALL.
J. D. HARPER.
S. H. HASTINGS.
D. S. JENNINGS.
GROVER KINZY.
W. A. LINTNER.
R. E. LOFINCK.
JAS. McADAMS.
G. W. MORGAN.
D. S. MYER.
A. J. OGAARD.
W. M. OSBORN.
A. W. PALM.
J. W. PAXMAN.
MARTIN REINHOLT.
R. R. REPPERT.
A. M. RICHARDSON.
J. C. ROBERT.
C. H. RUZICKA.
E. B. WATSON.
ISAAC WEISBEIM
W. A. WHEELER.
CASPER A. WOOD.
HARRY P. YOUNG.

### Members Deceased.

Malon Yoder.

### Change of Address.

P. V. Cardon, Experiment Farm, Moccasin, Montana.
Foersterling, H., care The Arbor Farm, Jamesburg, N. J.
Foord, J. A., 54 Lincoln Ave., Amherst, Mass.
Jensen, L. N., Box 1214, Amarillo, Texas.
Mackie, W. W., 121 Hilgard Hall, Berkeley, Cal.
Westover, H. L., Bard, California.
Wheeler, H. C., Agric. Bldg., Urbana, Ill.
Woodard, John, 381 Paisley Road, Guelph, Ont., Canada.

## NOTES AND NEWS.

A. R. Mann, who has been acting dean of the college of agriculture and director of the experiment station of Cornell University, has been made dean and director.

Walter Packard, formerly in charge of the Imperial Valley Experiment Farm at El Centro, Cal., is now chief of farm advisors for the southern half of California, with headquarters at Berkeley.

J. T. Parsons has been appointed soil technologist and O. I. Snapp has been made assistant in soils at the Ohio station.

Gordon W. Randlett, for the past two years director of extension in South Dakota, has been elected to a similar position in North Dakota.

Bernard F. Sheehan, formerly of the Iowa station, has been appointed instructor in farm crops at the Oregon college and station.

L. Van Es, for many years veterinarian of the North Dakota Station, has been elected director of that station.

C. W. Warburten, a member of the Committee on Seed Stocks of the U. S. Department of Agriculture, is now engaged in the purchase of seed grain for resale to farmers at cost in the sections of North Dakota and Montana where crops failed last year. This work is under the provisions of the emergency food production bill. Mr. Warburton's headquarters are in Minneapolis while engaged on this work.

W. R. Ward, instructor in agronomy, and Horace J. Young, assistant professor of agronomy, both of the University of Nebraska, are emergency district demonstration leaders in that state.

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## METHODS USED AND RESULTS OBTAINED IN CEREAL INVESTIGATIONS AT THE CORNELL STATION.[1]


H. H. LOVE AND W. T. CRAIG.


### INTRODUCTION.

During the past few years considerable interest has been manifested in the methods used in the various experiments of crop research, and considerable change in the handling of experiments in all agronomic investigations has resulted. This has been especially true with regard to the small grains. When, in addition to testing a few of the better-known varieties, selection and breeding work was undertaken, it was important to be able to handle a large number of sorts. This demanded a change in methods so that fair comparative results could be obtained without unnecessarily large acreage being devoted to any certain crop. The tendency has been to reduce the size of plat more and more until finally in a number of places the rod-row system has been adopted. So far as is known to the authors Mr. J. B. Norton, of the United States Department of Agriculture, was the first to put this method in general use.

Montgomery[2] has discussed this method in relation to plat trials. Since the authors in their work at the Cornell University Agricultural Experiment Station[3] have for a number of years been using

[1] Paper No. 64, Department of Plant Breeding, Cornell University, Ithaca, New York. Presented by the senior author, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Montgomery, E. G. Experiments in wheat breeding; experimental error in the nursery and variation in nitrogen and yield. U. S. Dept. Agr., Bur. Plant Indus. Bul. 269, 1913.

[3] This work is in cooperation with the Bureau of Plant Industry, United States Department of Agriculture.

this method rather extensively in connection with cereal breeding work it seems worth while to present some description regarding its details. In addition, the methods used in selection and hybridization will be discussed, with a brief statement of the results obtained.

### Methods Used in Making and Testing Selections.

Two methods are used in making selections with which to begin comparative trials. The first is to travel through the State making selections from various fields. In making these selections the different types present in the field are collected, as well as the main type represented. Care is taken to select from that part of the field which represents average conditions as nearly as can be ascertained. Heads are selected rather than plants, owing to the difficulty of separating individual plants with certainty. In this sort of selection it is important to make collections from as many different fields as possible and to cover a wide area, so that various growth conditions may be encountered.

The second method followed is to make plantings of a selected variety or varieties from which selections are to be made. Individual kernels are planted 1 foot apart each way in ground previously prepared and marked off. In this way it is possible to study the entire plant and make comparisons as to stooling habits, stiffness of straw, and the like. An objection to this method is that it is not possible to make selections on such a large scale as when they are made from the field. That is, from the field the selections represent the best from a vast number while from the hill method they represent the best from only several thousand at most. This objection is partly offset by the fact that a more detailed study can be made of the individuals selected and that a larger quantity of seed is obtained than is possible from a single head. In either case it is very important to start with a very large number of heads or plants.

After these heads are selected they are then thrashed and prepared for planting. Few notes are taken on the heads as the more detailed study of the new sorts is made later on in the trials. For thrashing these heads a small head-thrasher has been constructed by Mr. H. W. Teeter, of the Department of Plant Breeding. No screen or fan is attached to this machine, as it is used also for a great amount of statistical work where all kernels, even the light ones, are to be saved. A small electric motor furnishes the power. Very rapid work can be done with this machine, which is operated by one man. A hundred or more heads can be thrashed and cleaned per hour.

When heads are selected the seed is sown in head rows the first year. In order to have a uniform seeding the seeds are counted out so that the same number may be sown in each row. The seeds are placed in an envelope and this envelope numbered with the proper row number. Sometimes it is necessary to sow in two lots, as it is not always possible to obtain the same number of seeds from each of the heads chosen. For example, it may be necessary to plant a series where 30 seeds per row and another where 25 seeds per row are used.

For wheat these head-rows are now 2.5 feet long and for oats 5 feet long. Usually 25 or 30 seeds are used in each head row for wheat and 40 to 60 for oats. As stated above, the number of seeds used depends on conditions affecting the size of head selected.

These seeds are scattered in the drills thinly and are not spaced, as experience has shown that for such work careful spacing is not necessary. It is more important to have a very large number of selections under test and depend on them to furnish something worth while than to handle a few selections with greater attention to detail. For example, this year we have under test 2,200 new selections of wheat and two years ago we had 1,600. It is our plan to start a new selection series every two years. This works out to better advantage than starting a series every year, as it gives time for the elimination of the poorer sorts. The number of head rows of wheat that can be sown in a day by five men is about 2,000 to 2,500, while for oats it is less, as the row is longer and more seeds are to be dropped.

If plants rather than heads have been used as a basis for selection then more seed is available and a definite quantity of seed may be weighed out for each plant row. Weighing may be objected to since the number of seeds from a large-seeded sort will be less than from a small-seeded one. It has been shown, however, that within a rather wide range the difference in number of seeds will not affect the final results. With plants it will be possible also to have longer rows than with heads.

It may be worth while to mention how these drill rows are prepared for sowing. The land to be used is put in as good tilth as possible. Then a sled marker with runners a foot apart is used to mark off the field. This is then followed with a single-shovel plow to open the drills. When the ground is in good condition a little Planet, Jr., plow with disk attachment is used for covering; otherwise, hoes are used. The marker and drill are started a little while before sowing, marking and opening the drills across the plat of

ground to be used. This makes for more rapid work, as the rows are all laid out before any stakes or lines are placed. The rows and paths between the series can then be measured off and lines run to mark the end limits for a large number of rows at once. This plan is used whether head or rod rows are to be sown.

While the plants in the head rows are growing and developing general notes are taken which with the yield of grain help to determine the worth of a particular selection. At harvest time the rows are studied, usually by two persons, and those rows that are apparently superior are harvested and tagged. No selection of plants from these rows is made, as it is not possible to change the type by reselecting plants from these rows which, barring accidental crossing, are already pure lines. Some natural crossing occurs with wheat; these hybrid rows are usually discarded. No natural oat hybrid has yet been found. A large number of the head rows are left in the field because they show clearly that they are not worth continuing. It may be argued that one year's test is not sufficient to determine the value of a selection. This may be partially true, yet if these selections have been made from varieties adapted to the locality it would be expected that the better selections would show up well the first year. Then, too, the selection of these head rows is not made so closely but that practically all of the better ones are retained. About three fourths of the rows are usually discarded the first year. We feel that by discarding in this manner and bringing in new selections every second year as indicated greater progress will be made than by keeping a large number of strains of doubtful value.

These head rows are then thrashed and the grain weighed and recleaned for sowing the second year. After thrashing a few of the poorest may be discarded, although as a rule those that have passed the field inspection are retained for at least one more year. These selections are sown in triplicate rod rows the second year provided there is enough seed; if not, they are sown in duplicate rod rows.

The amount of seed to be sown per row is calculated from the usual rate of seeding for any particular grain. The seed is weighed and put into envelopes and the envelopes numbered with the proper row number according to the plan of planting. After all of the envelopes are numbered these numbers are checked with the plan of planting to be sure all are in their proper order. A check row is sown every tenth row. Seed for this check is taken from a standard sort or an improved strain. The check rows are marked with numbered stakes which serve as an aid in taking notes and harvesting.

In this way any variations in soil differences may be determined. The seed is sown by hand from the envelopes and it is possible for five men to sow 1,000 to 1,200 rows a day. It is found that with a little experience in sowing the seed can be distributed just as evenly as with a drill.

The plan of planting is arranged so that no two rows sown from the same sort come together. For example, if there are 144 sorts to be tested these together with the check rows will make 160 rows. This series of 160 rows is sown and the series is then repeated; that is, row 161 is the same as row 1, 162 the same as 2, and so on for the entire series. In order to prevent any effect which may be caused by two unlike sorts growing together the different strains are arranged according to earliness and other characters so as to reduce this source of error to a minimum. Some of the rod rows of wheat are shown in Plate 4, figure 1.

The length of these so-called rod rows varies, depending on the kind of crop being handled. All of the weights of grain are taken in grams and the yields per row estimated in bushels per acre. In order to make these calculations as simple as possible the length of the row is so changed that some simple factor is used to convert grams per row into bushels per acre. The oat rows are 15 feet long and the grams per row are multiplied by 0.2 to obtain bushels per acre. For wheat the length is 16 feet and for barley 20 feet, the conversion factor in each case being 0.1.[4]

In every case it is desirable to sow longer rows than are harvested. With oats and barley these rows are sown 1 foot longer, or 16 and 21 feet, respectively. For wheat, which must stand through the winter, the row is 2 feet longer or 18 feet. It is obvious that if the end of each row is cut off, more nearly uniform conditions may be obtained and the effect of increased nutrition which occurs at the ends will not enter into the calculations and modify the results.

During the growing season any desired notes are taken on the rows, such as disease resistance, height, habit of growth, type of head, and the like. At harvest time the rows are cut and carefully tagged and bound. The bundles are bound near the butt with twine, while wired Denison tags which have been previously numbered in accordance with the plan of planting are used to tie the bundle near the heads. When harvesting rod rows it is better to have three men in a team, two to cut and one to tie and label the bundles. A pole

[4] These factors are in reality 0.200066 + and 0.100033 +, but the remainder of the fraction is so small that it does not affect the result when only the first significant number is used in each case.

of the proper length is used to cut the rows by so that the exact length is harvested. Three men will cut from 300 to 400 rows a day. The bundles are not bagged to prevent mixing but are taken immediately into the thrashing shed and hung heads down in the same order that they are grown in the field. This method of hanging (Plate 4, fig. 2) was designed by the junior author and is so planned that ten bundles can hang in a row. These are hung on nails driven into strips. The system is flexible so that the different quantities of straw can be accommodated. These strips rest on supports which are hung from the roof of the building. These supports are $2 \times 6$ inches and one of them is notched at various distances so that the strips may be held in an upright position. These notches make it possible to shift the strips in accordance with the quantities of straw and size of the bundle. This system allows the grain to dry thoroughly without mixing and keeps it in good condition until thrashing. When the grain is cared for in this manner the thrashing of oats and barley may be left until the wheat is thrashed and sown again and the other summer work finished.

At thrashing time the three bundles of each sort are gotten out, which is easily done by the system of hanging. These bundles are thrashed individually, but it is not necessary to clean the machine thoroughly after every row as would be the case if the bundles were taken out of a pile just as they came. It is only necessary to clean the machine thoroughly after each variety, thus facilitating thrashing. Before thrashing the total weight of straw and grain is taken and after the grain is thrashed and weighed the yield of straw may be obtained by taking the difference between total weight and weight of grain.

The thrashing of these rod rows is done by means of a specially constructed machine designed by Mr. H. W. Teeter, of the Department of Plant Breeding. This machine is so built that the screens are in sight and after finishing with one sort if any grain remains behind it can be seen and brushed out. The thrashing can best be done by four men. One man can follow the plan of planting and get out the bundles, one do the feeding, one bag and label the grain, and the fourth can look after the machine and take care of the straw. It is possible to thrash about 500 to 600 rows of wheat and 450 to 550 rows of oats in a day.

As the different rows of each sort are thrashed at the same time they can be kept together and the work thus simplified. After the individual weights of row are obtained the grain from the several

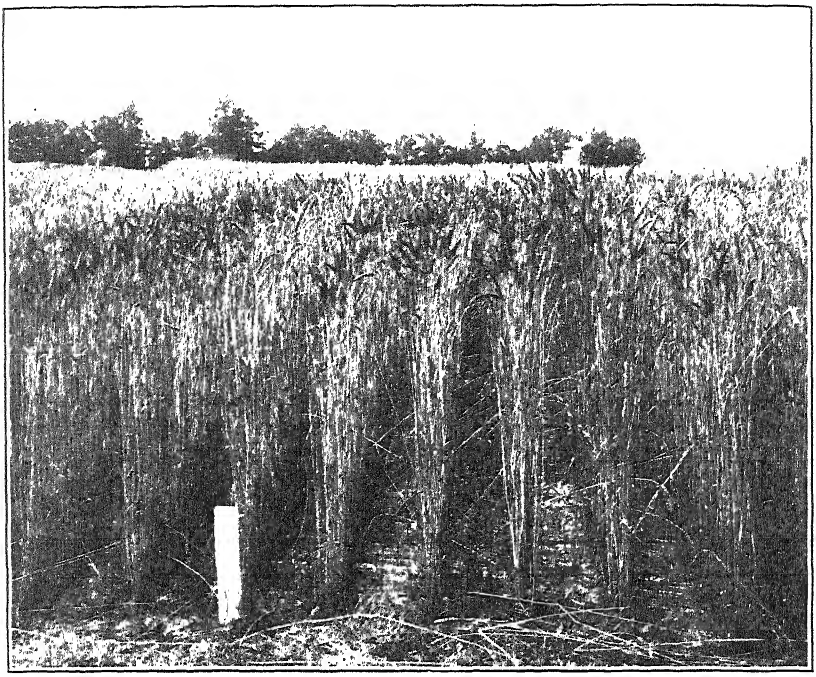

FIG. 1. View of rod rows of wheat at the Cornell Station.

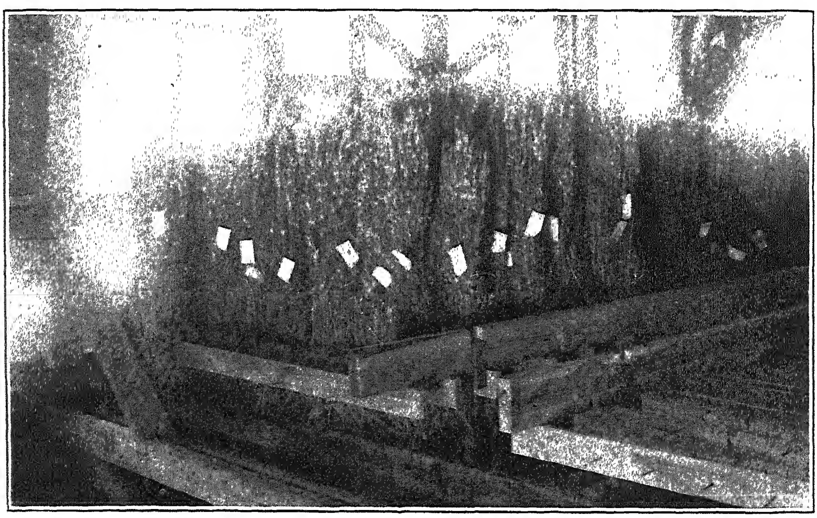

FIG. 2. Method of hanging bundles from rod rows.

rows is brought together, weight per bushel tests are obtained, and the seed prepared for sowing another year. These weights per bushel are taken by means of an apparatus described in a previous article,[5] which gives very accurate results. The variation between different determinations of the same variety is very small. This apparatus is similar in operation to one described more recently by E. G. Boerner.[6]

The selections for further testing are then made, basing them on yield and other qualifications. In the third year of this test those sorts that are continued in the rod-row series are repeated ten times, with a check every tenth row the same as the second year (Plate 4, fig. 1). The method of handling, so far as sowing, measuring the rows, and the like are concerned, is the same as has been described.

At thrashing time the ten bundles of a sort are brought together. These are thrashed by individual rows in order to have the data to study the variation of the same sort in different parts of the field. If such data are not desired then it is possible to thrash all ten bundles together, letting the total weight represent the yield of the sort under the conditions tested. This eliminates a great deal of the detail work of thrashing, thus making it possible to thrash about 30 sorts of 10 rows each per hour.

The different strains are continued in the rod-row series for at least three years before any one is eliminated unless it is evident that a particular strain is not at all adapted to the given locality. In addition to the rod-row series a few of the better selections which give evidence of superior merit are grown in increase plats. These increase plats vary in size from year to year, depending on the number of sorts to be grown and the land available. They are so planned, however, that they may be run in duplicate or triplicate and therefore be of use as variety tests.

Any new sorts which have given good yields for a number of years are then tested further by sending seed to farmers who are willing to cooperate to the extent of making comparative trials of the new sort with the varieties grown in their locality.

The value of the rod-row system has been much discussed and various objections have been made to its use. The tendency now, however, is to give this method its rightful place in agronomic technic.

[5] Love, H. H. Methods of determining weight per bushel. *In* Jour. Amer. Soc. Agron., 7: 121–128. 1915.

[6] Boerner, E. G. Improved apparatus for determining the test weight of grain, with a standard method of making the test. U. S. Dept. Agr. Bul. 472. 1916.

To those who have given careful thought and study to plat methods it is evident that by using a rod-row system and replicating a sufficient number of times the probable error of the average yield is reduced to a very low degree. This is illustrated by some data presented here which are taken from some of the rod-row records.

Wood and Stratton[7] have said regarding the use of small plats that for very small plats of one-one thousandth to one-five thousandth of an acre the probable error may be reduced by replicating the plats systematically. They predicted that the probable error of one such plat could be reduced to about 12 percent and that for nine such plats to about 4 percent..

The rod-row plats are about half way between the two sizes of plat mentioned. It is of interest then to present some data on the yields of rod rows repeated ten times. These yields, with the means and probable errors, are given in Table 1 for some varieties of wheat and oats.

TABLE 1.—*The average yield and probable errors and probable error as percentage of the mean of some varieties of wheat and oats tested by the rod-row method.*

WHEAT.

| Variety. | Mean and probable error. | Probable error as percentage of the mean. |
|---|---|---|
| Jones Longberry | 44.70 ± 1.42 | 3.18 |
| Dawson Golden Chaff 522–68 | 42.09 ± 1.00 | 2.38 |
| Gypsy | 41.88 ± 1.23 | 2.94 |
| Gold Coin | 39.11 ± 1.06 | 2.71 |
| Harvest King | 39.04 ± 1.46 | 3.74 |
| Rural New Yorker No. 57 | 37.94 ± .97 | 2.56 |
| Fishhead | 37.17 ± .48 | 1.29 |
| Average | | 2.69 |

OATS.

| Variety. | Mean and probable error. | Probable error as percentage of the mean. |
|---|---|---|
| Welcome selection 123–5 | 80.40 ± 2.90 | 3.61 |
| Silvermine | 76.64 ± 2.33 | 2.90 |
| Silvermine selection 120–9 | 75.20 ± 2.19 | 2.91 |
| Sixty Day 5938–1 | 73.60 ± 1.22 | 1.66 |
| Lincoln | 72.28 ± 2.36 | 3.27 |
| Heavyweight | 72.18 ± 2.60 | 3.60 |
| Burt × Sixty Day | 59.52 ± 2.32 | 3.90 |
| Average | | 3.12 |

These are only a few of the many tests, yet as the varieties were selected at random they fairly represent the average condition for

[7] Wood, T. B., and Stratton, F. J. M. The interpretation of experimental results. *In* Jour. Agr. Sci., vol. 3, part 4. 1910.

wheat and oats. It is seen that the probable error of the mean, expressed in percentage, varies between 1.29 and 3.74 for wheat and between 1.66 and 3.90 for oats. The average of the probable errors expressed in percentage is 2.69 for wheat and 3.12 for oats, which is well within the limits predicted for such work by Wood and Stratton.

The relation between the rod-row yield and plat yield for a few varieties grown the same year has been plotted graphically (fig. 24) in order to show the relation between the yields of the same strains tested under the different conditions. The broken line represents the yield of the rod rows of wheat for 1916, while the solid line represents the yield of the same strains tested on one two-hundredth-acre plats repeated three times. The yields do not follow in exact order but in general the relationship holds. This is well illustrated by means of the straight line fitted to the plat yields. The equation to this line is $y = 37.253 + .177x$. When one considers the fact that for the rod rows and drill plats it is very difficult to have all conditions similar the variation between the two methods is not unexpected. The relation between the yields of the two methods is practically the same as the data published by Montgomery show.

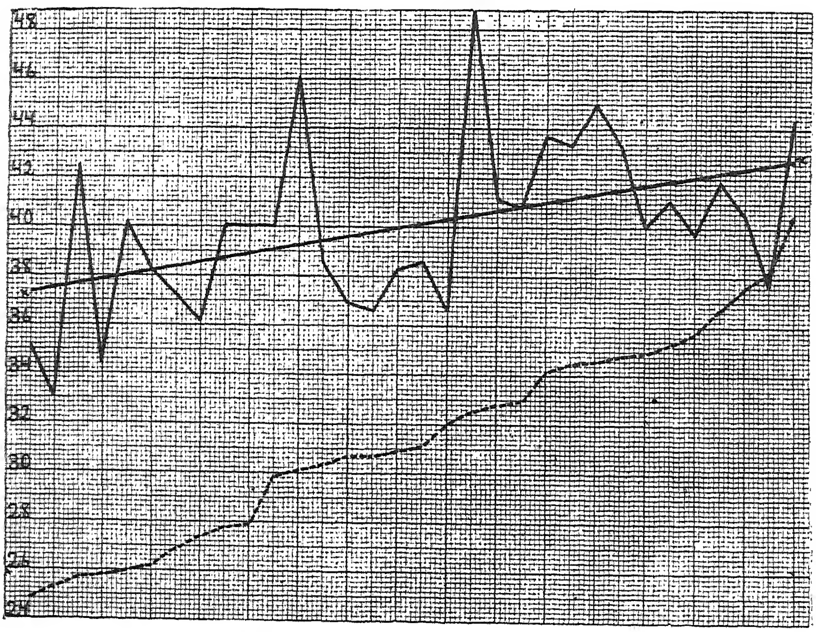


FIG. 24. Graph showing relation of yield of wheat varieties in 1916 when same sorts were grown in rod rows repeated ten times and in two-hundredth-acre plats repeated three times.

This chart also shows a marked difference between the yields of the rod rows and the plat yields. The plat yields are with one exception considerably higher than the row yields. The average for all the plats is 40 bushels per acre, while for the rows of the same varieties it is 31.4 bushels. This overcomes the objection often made against the rod-row system that the yields are higher than plat trials. To be sure, there is some difference in stand under the two systems.

As the probable error is reduced so low with rod rows one seems justified in using this method, as so many more sorts may be handled on a given area. For example, with oats when the rod rows are repeated ten times they comprise altogether about one two-hundred-ninetieth of an acre which, together with the required paths between the series, makes it possible to handle about 242 sorts repeated ten times on an acre. On the other hand, with two-hundredth-acre plats repeated three times and with 2-foot borders between, it is possible to handle only about 37 sorts. With these facts in mind we feel that for our purpose the rod-row method is the best.

TABLE 2.—*Three-year average yields in bushels per acre of oat and wheat varieties and selections, with the increases obtained.*

OATS.

| Variety and selection numbers. | 3-year average yield per acre. *Bushels.* | Gain. *Bushels.* |
|---|---|---|
| Canada Cluster | 56.9 | |
| Canada Cluster 110–36 | 65.6 | 8.7 |
| Lincoln | 53.2 | |
| Lincoln 109–14 | 57.4 | 4.2 |
| Lincoln 109–15 | 58.4 | 5.2 |
| Big Four | 52.4 | |
| Big Four 115–27 | 58.3 | 5.9 |
| Big Four 115–40 | 57.9 | 5.5 |
| Clydesdale | 50.2 | |
| Clydesdale 114–2 | 56.7 | 6.5 |
| Clydesdale 114–4 | 57.1 | 6.9 |
| Clydesdale 114–14 | 57.8 | 7.6 |
| Clydesdale 114–16 | 58.0 | 7.8 |

WHEAT.

| | | |
|---|---|---|
| Klondyke | 28.2 | |
| Klondyke 126–26 | 30.4 | 2.2 |
| Klondyke 126–44 | 31.3 | 3.1 |
| Fulcaster | 26.0 | |
| Fulcaster 123–23 | 27.9 | 1.9 |
| Fulcaster 123–32 (beardless) | 30.2 | 4.2 |
| Red Wave | 27.7 | |
| Red Wave 128–47 | 31.1 | 3.4 |

Some of the results obtained by this method of selection and testing are shown in Table 2.

It may be well to summarize the methods used in making selections. The heads or plants are selected and tested for one year in head or plant rows. The best rows are selected in the field, harvested, thrashed and grown the second year in rod rows repeated two or three times, depending on the amount of seed available. Only the very poorest are eliminated the second year. The rest are continued in rod rows repeated ten times for at least three years. The best new strains are multiplied and tested in increase plats. The best ones are finally distributed to farmers for further comparison. In this way a sort is tested for at least six years before it is finally put into general use.

### Methods Used in Making and Studying Hybrids.

In making hybrids of the small grains it has been found best to grow the plants to be used for hybridization in pots in the greenhouse. Experience has shown that in most seasons when the plants are grown in the field the hot sun dries up a large number of the flowers which have been emasculated, thus greatly interfering with the work. Another point in favor of growing greenhouse plants is that pollen is available for more hours per day and that the pots can be moved about, thus bringing those being worked close together. The plants, especially in the northern States, develop more slowly in the greenhouse, thus giving more time to complete the work. Another very important point is that the work may be done in the late winter or early spring before the heavy field work of summer comes. Loss from injury by storms is also avoided.

In crossing oats several spikelets on a head are chosen at a time when the anthers are still young and are green in appearance. The smaller or upper flower (or flowers) is removed from each spikelet and the anthers removed from the remaining flowers by means of a small pair of forceps. The spikelets are then tagged with a tag which shows the date of emasculation. After a day or two the flowers are pollinated. This is done usually by collecting anthers that are just ready to burst, placing one in the flower, and carefully replacing the palea. Sometimes when plenty of pollen can be obtained the pistils are dusted with pollen. At other times anthers which are nearly ripe are taken from the plants used for male parents and dropped into the flowers at the time of emasculation. All these methods have given very good results.

In all cases a record is kept showing which particular plant of a variety was used as a male parent. When the hybrid seeds are ripe they are collected, as are also seeds from both the male and the female parents. These seeds are sown in pots again in the greenhouse. Greater care can be given them there than in the field and there is a greater possibility of saving all the plants. Seeds from each of the parents are also grown in order to make direct comparisons between the $F_1$ plant and the parent types. The seeds from the $F_1$ plants as well as the parents are saved and the various characters described and noted.

The $F_2$ and succeeding generations are grown in the field in 5-foot rows. The rows are prepared in the same manner as for the rod rows. In sowing, the kernels are spaced 2 to 3 inches apart in the row. This spacing is not made by exact measurement, as that is unnecessary. One row of each of the parents is also sown for comparison. The 5-foot rows with a 2-foot border between the sections permit the taking of notes on the plants without interfering with their growth. It is also possible to sow more rapidly, as it is possible to guage the spaces needed by the number of seeds in hand. A row may be confined to a single sort, while if longer rows are used it is necessary sometimes to have more than one sort in a row, which leads to confusion and possibly to errors.

At harvest time the plants are pulled if it seems necessary to save seed from a large number. When this is not needed the plants are pulled and a culm cut from each for further study. By saving only a culm it is possible to store a large number of families in a small space. When this latter method is used all of the heads from a fairly large number of different types are saved in large envelopes. In this way seed is retained for the next planting. Unless one saves a rather large number it may be found that not all the types desired are present. In certain wild oat crosses it is necessary to use envelopes for many of the plants to prevent loss by shattering.

When wheat is to be crossed some of the spikelets are removed near the middle of the head, and either the upper or lower flowers emasculated. All but the outside flowers of the spikelet are removed. In some cases the tips of the glumes are cut off and the anthers removed, while at other times the anthers may be removed without clipping the glumes. The heads are then covered with glassine bags made for the purpose. Either way of preparing the head is satisfactory, as the data in Table 3 show:

TABLE 3.—*Results of two methods of emasculation for wheat pollination.*

| | |
|---|---|
| Number of heads worked | 90 |
| Number of heads setting seed | 67 |
| Percentage of heads setting seed | 74.44 |
| Percentage of heads setting seed when glumes were clipped | 74.35 |
| Percentage of heads setting seed when glumes were not clipped | 74.51 |
| Average number of seed set | 7.2 |
| Average number of seed set when clipped | 8.5 |
| Average number of seed set when not clipped | 6.2 |

From these data it is seen that there is practically no difference as to results whether the glumes are clipped or not. This method may be objected to because pollen from the non-emasculated flowers of the head may adhere to the glassine bags so that when they are removed for pollination some of it may fall on the emasculated flowers. Experience does not seem to give this objection any weight. Wheat hybrids in general are handled in the same way.

Most of the notes on these hybrids are taken in the laboratory rather than in the field, though certain notes which can be more readily taken in the field are secured. It is difficult to handle as large a number as we now have and take many notes in the field, particularly as the various sorts soon begin to weather badly and therefore are much discolored. Again, certain crosses of *Avena* species shatter badly unless the plants are harvested rather early.

In addition to the studies in inheritance, any hybrids that give promise of commercial value after becoming fixed as to their characters are placed in the rod-row series for testing.

Space does not permit a full account of the results obtained, yet it is well to mention a few. With oats, color studies have been made in various crosses. In *Avena fatua* × *A. sativa* (variety Sixty-Day) crosses it is found that the yellow color of the Sixty-Day apparently inhibits awn production as well as the production of pubescence. In a cross between two black oats classed as the same type, non-black oats appear in the second generation in the ratio of 15 black to 1 non-black. Crosses between hulled and naked oats show that these characters behave as a simple monohybrid, but that there is apparently some modifying factor present which affects the amount of hull in the heterozygous forms.

With wheat the red color of kernel is found to be represented by one, two, and three factors in inheritance. This is in accordance with the results of other workers. Many crosses between the different species are being studied. Two fertile wheat-rye hybrids have been found, one of which has been carried to the fourth generation.

# A SIMPLE METHOD OF DEMONSTRATING THE ACTION OF LIME IN SOILS.[1]

Paul Emerson.

Every demonstrator or lecturer realizes the fact that the more vividly he paints his word pictures the more lasting is the impression made on his audience. If the lecture is illustrated it is better understood, even with a poor lecturer, than if not, and the closer the illustrations are to the point the better.

While demonstrating methods for testing soils and determining their lime requirements at a large State fair recently, the writer was asked this very pointed question: "How can you prove to me that limestone has a beneficial action in the soil by neutralizing the acidity?"

The questioner was of the type that demands to be shown rather than told, and his question was answered in the following manner. A few drops of sodium alazarin sulfonate (alazarin red) indicator was put into about 100 c.c. neutral water in a flask. The farmer was asked to note the resulting brown color and also any other change of color that might subsequently appear. Approximately 2 grams of ground limestone were then dropped into the water and the flask thoroughly shaken. Naturally the characteristic alkali color appeared. This state was assumed to be that of a soil in good tilth. But practically all farming operations tend toward an acid reaction, so a few drops of dilute hydrochloric was added. The farmer was quick to note the solution's change from red to yellow, but when the flask was agitated a few times and the alkali color returned, he was amazed. When the phenomenon was explained to him in a manner that applied to the soil, he was apparently convinced that the beneficial action of limestone in the soil continued as long as there was any present.

This demonstration proved to be very popular and absolutely settled a number of arguments. It is hoped that lecturers on limes and liming will be able to make use of the method, as the materials required take up little room and are found in practically all laboratories.

[1] Contribution from the Maryland State Agricultural Experiment Station, College Park, Md. Received for publication November 13, 1917.

# GLANDULAR PUBESCENCE IN VARIOUS MEDICAGO SPECIES.[1]

ROLAND MCKEE.

In a study of the occurrence of glandular pubescence in the various species of Medicago, an attempt was made to determine to what extent this character varies with environmental conditions. It has been observed that glandular pubescence is much more strongly developed in some species than in others. Certain species of Medicago have glandular pubescence on stems, leaves, and pods; others on the pods only; while some have none at all. Of the species studied the following have glandular pubescence strongly developed on the pods at least: *M. soleirolii, M. rigidula, M. minima, M. disciformis, M. blancheana, M. tunetana, M. falcata viscosa,* and *M. gaetula.* Other species having glandular pubescence less well developed or showing only under certain conditions are *M. murex sorentinii M. orbicularis, M. lupulina,* and *M. sativa.*

In some species of Medicago it has been noted that very minute glandular hairs may be present on the young green pods and disappear with later development. In other species in which only minute glandular hairs occur early in the season, both young and mature pods have well-developed glandular hairs later during hot, dry, and adverse weather conditions. Thus in plants in which glandular hairs can be noted on the pods early in the season only with a low-power compound microscope, glandular pubescence is quite strongly developed later in hot, dry weather.

Inasmuch as subspecific distinctions have been made in various species of Medicago on the presence or absence of glandular pubescence, the variability of this character is of value in determining the validity of such classification. In these studies *M. lupulina* and *M. orbicularis* have been especially noted. Individual plants have been observed throughout the season with regard to glandular pubescence development.

On April 27, 1915, at Chico, Cal., a plant of *M. orbicularis* was observed as having both young and well-developed pods that were not glandularly pubescent as the term is usually used but had glandular pubescence which could be seen with a low-power compound micro-

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

scope. On May 27, 1915, this same plant was noted as having both young and mature pods with well-developed glandular pubescence, that is, the glandular pubescence was sufficiently well developed to be seen without magnification. On April 27, 1916, at Chico, Cal., the pods of a plant of *M. orbicularis* were observed as not glandular. The most advanced pods were well developed but not mature. A hand lens only was used in making this observation. On May 27, 1916, at which time some of the pods were mature, this same plant was noted as having pods not glandular, while on July 7 it was noted as having both young and mature pods that were very glandular. General observation of numerous plants of *M. orbicularis* and its subspecies in the field have shown that early in the season none of these has pods in any stage of development that show glandular pubescence, while later in the season or after hot, dry weather has prevailed for some time practically all plants have pods in all stages of development with strongly developed glandular pubescence. In *M. orbicularis* glandular pubescence has been observed in no case as occurring other than on the pods.

Observations made regarding glandular pubescence in *M. lupulina* show the same fluctuating variation due to environmental conditions as that noted in *M. orbicularis.* However, there are also some indications that in this species some forms have glandular pubescence throughout their existence regardless of environmental conditions while others are never glandular. In the common form of this species, wherever observed, glandular pubescence is not present early in the season regardless of the stage of development of the plant, while later in the season it is quite conspicuous. In *M. lupulina* glandular pubescence may occur on the stems, leaves, and pods, but when not well developed it is most conspicuous on the pods. Plants of *M. lupulina* collected at Chico, Cal., on May 18, 1909 show young pods glandular. Plants collected at Chico June 5, 1912 show no glandular pubescence. Plants collected at Chico May 6, 1914, while in general not glandular, show a very few glandular hairs forming. Plants collected at New London, Ohio, June 28, 1915 show pods mostly nonglandular but with few glands forming. On April 27, 1915, at Chico, Cal., a plant of *M. lupulina* having pods well developed was observed as not glandular. On July 15 this same plant was noted as very glandular. On April 26, 1916 a plant of *M. lupulina* was observed at Chico, Cal., as not glandular. On May 8, 1916 this same plant was noted as not glandular, while on July 13, 1916 it was noted as very glandular. A plant of *M. lupulina* growing at Elyria, Ohio, was ob-

served on June 19, 1917 as not glandular. This same plant on August 23 was noted as not glandular, while on October 18 it was noted as very glandular.

In the summer of 1916 a plant of *M. lupulina* growing at Albany, Ore., was observed as not having glandular pubescence, while at the same time plants growing nearby were quite glandular. Seed from the non-glandular plant was collected and grown at Chico, Cal., in 1917. At no time did the plants grown from this seed show glandular pubescence.

From observations made in the cases of *M. lupulina* and *M. orbicularis* it is very evident that the occurrence of prominent glandular pubescence may be due to environmental conditions, these conditions apparently being hot, dry weather and unfavorable soil-moisture supply.

Some interesting observations have been made with regard to glandular pubescence in various varieties and hybrid forms of *M. sativa* and *M. falcata.* A large number of introductions of these species and subsequent hybrids made from these introductions have been observed to determine to what extent glandular pubescence might occur. Aside from one introduction of *M. falcata,* which had been identified as *M. falcata viscosa,* none have strongly developed glandular pubescence. However, glandular pubescence developed to some degree has been noted in a number of *M. falcata* forms. In the case of *M. sativa,* or common alfalfa, glandular pubescence was found in only two instances. In the case of *M. falcata* (excepting *M. falcata viscosa*), and also in *M. sativa,* the glandular forms are apparently hybrids, though they show but little variation in other characters.

On April 28, 1915 the pods of a large number of species of Medicago were examined to determine the presence or absence of glandular pubescence in species in which it might occur. Both macroscopic and microscopic observations were made. In such species as *M. scutellata* and *M. rugosa,* in which glandular pubescence is always present, long, well-developed glandular hairs were very conspicuously present to the unaided eye. In other species, such as *M. orbicularis,* which has strongly developed glandular pubescence in midsummer, glandular pubescence was present but only microscopically. Other species, such as *M. hispida* and its subspecies, which have not been noted as glandular late in the season, had microscopic glandular pubescence on the young pods. In a number of species the glandular hairs per square millimeter were counted and the length of the hairs and the length and width of the glands were determined.

In the case of *M. orbicularis* the maximum length of the hairs was 63 microns, while the glands of maximum size were $36 \times 20$ microns. Later in the season the glandular pubescence of this species measures practically the same as *M. scutellata,* the hairs being about 600 microns in length and the glands about 50 microns in length. In the case of a number of species such as *M. hispida, M. echinus, M. obscura helix, M. intertexta,* and *M. tuberculata aculeata,* microscopic glandular pubescence was noted on the pods early in the season, but in no case have these been noted as developing further.

The number of glandular hairs per square millimeter varied considerably in the different species. In the case of *M. scutellata* and *M. rugosa,* in which species the glandular hairs were well developed, the number was so many that they could not be definitely counted. With the species having only microscopic glandular hairs the number varied from 40 to 120 per square millimeter.

The data here presented seem to show clearly that in certain species of Medicago glandular pubescence varies decidedly with environmental conditions, and for this reason it can not be depended upon as a constant character in determining subspecies.

## CUTTHROAT GRASS (*PANICUM COMBSII*).[1]

C. V. Piper.

*Panicum combsii* Scribner and Ball was described[2] from specimens collected "in damp, fertile flat woods" at Chipley, Washington Co., Fla., in the northern part of the State. Hitchcock and Chase[3] record it from three localities in southern Georgia, four stations in northern Florida, and one station each in southern Alabama, southern Mississippi, and southern Louisiana, and give as its usual habitat "margins of ponds and wet woods." From these data it would appear to be a rare species. During the past season the writer found it enormously abundant in Polk County, central Florida, where it is known as "cutthroat grass," and the peculiar areas in which it occurs

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication February 4, 1918.

[2] Scribner, F. Lamson-, and Ball, Carleton R. Studies on American grasses. U. S. Dept. Agr., Div. Agrost. Bul. 24: 42–43, fig. 16. 1901.

[3] Hitchcock, A. S., and Chase, Agnes. The North American species of Panicum. Contr. U. S. Natl. Herb. 15: 106–107. 1910.

in nearly pure growths are known as "cutthroats." The grass is said to be abundant in similar areas in Osceola County to the eastward, and in De Soto and Lee counties to the south. A "cutthroat" usually if not always occurs on seepage areas on the sides of slopes, especially of sand ridges. At these seepage places an abundance of water exudes, so that even in extremely droughty seasons, as in the spring and early summer of 1917, water can be obtained at shallow depths, a fact utilized by stockmen. The soil of a "cutthroat" consists of a very fine, slippery, black muck a foot or more in depth. These areas are treacherous, and in spite of the heavy cover of grass wagons and automobiles easily become bogged. Such areas vary in size from one to many acres, and often successions of them occur up the side of a gentle slope.

Cutthroat grass grows in dense tufts, the tough wiry leaves being nearly erect and 6 to 18 inches long. In typical cutthroat soil the plant rarely blooms. In the neighborhood of Florinda, Fla., however, abundant specimens were found in late bloom November 4, 1917.

According to Mr. W. F. Ward, the superintendent of the Kissimmee Island Cattle Company, the stockmen of the region are in accord as to their experience with this grass as a forage. They consider it good fattening winter feed for adult steers and for non-pregnant cows, but that pregnant cows abort when pastured on this grass, and that young animals die. So fixed is this opinion that stockmen govern their operations accordingly. Locally the disease is known as "salt sickness." "Salt sickness" has several times been investigated in Florida. Stockbridge, French, and Ennis[4] summarize their investigations as follows:

1. The disease known locally as "salt sickness" is not believed to be a specific *disease*, but rather a *condition* resulting from improper environment, especially insufficient nutrition.

2. Similar occurrences have existed elsewhere and are usually confined to regions where the predominating soil is light, sandy, comparatively lacking in nutritious qualities, Cape Cod peninsula in Massachusetts being a locality similarly affected.

3. The condition is most prevalent at the end of the winter season, when animals have been for several months confined upon range or pasture consisting of the dry wire-grass and other inferior vegetation of the sand ridge portion of the State.

4. The disease is distinctly digestive in character, has its seat in the alimentary canal and finally develops into chronic inflammation of the small intestine, resulting in malnutrition, anæmia and frequent death from starvation.

[4] Stockbridge, H. E., French, W. E., and Ennis, J. E. Salt sickness. *In* Fla. Agr. Expt. Sta. Rept. 1900–01, p. 43–58. 1902.

5. The symptoms show those generally attendant upon chronic anæmia: loss of flesh, loss of appetite, or abnormal appetite, including craving for foreign substances like earth, sand and bone, and diminishment of red blood corpuscles, as evidenced by thinness of blood, swelling or ulceration under the jaw and white bloodless appearance of mucus membranes particularly inside of the mouth and eyelids.

6. Alimentary correctives and tonics are suggested as counteracting these conditions.

7. The change of affected animals to new range or pasture is both preventive and curative in effect.

8. The use of lime water and gentian or iron salts have proved invariably beneficial and during our investigation of the subject not an animal thus treated died, but all eventually recovered normal condition. Air-slacked lime $\frac{1}{2}$ ounce, and sulphate of iron $\frac{1}{8}$ ounce, are recommended in 3 gallons of water, the former as often as the animal will drink and the latter daily.

Similar conclusions are reached in a separate publication by Dr. W. E. French.[5] Dr. C. F. Dawson,[6] however, reaches a different conclusion:

From what I have seen of "salt-sick" and from what we know of Texas fever, the rôle which it should play in diseases of cattle in the South, and especially in Florida, where the tick is ever-present, I am forced to believe that "salt-sick" is chronic Texas fever and that the conditions named by Dr. Stockbridge as being the cause of the disease are not the *sole* causes, but are contributing causes. The loss of appetite which occurs early in "salt sick" cannot in all cases be attributed to poor pastures and it would occur, regardless of pasture conditions, in an animal attacked with Texas fever.

In all cases of "salt-sick" where I have had an opportunity of making a post-mortem examination, I have found the appearances to be those which are attendant upon the extreme anæmia which follows an attack of Texas fever. These are pale, watery blood, dropsical conditions, light-colored, bloodless liver and extreme emaciation. Most important of all was the occurrence in fairly large numbers of the germ of Texas fever in the red blood corpuscles, in the omental fringes, and of ulceration of the pyloric end of the fourth or true stomach.

The subject so far as "cutthroats" are concerned is one that merits careful investigations as the alleged facts seem to be connected with the grass. Botanically the subject is of interest because a grass otherwise rare is enormously abundant in the peculiar soil areas to which it is adapted.

[5] French, W. E. A study of salt-sick cattle. *In* Amer. Vet. Rev., 25: 985–991. 1902.

[6] Dawson, C. F. Texas cattle fever and salt sickness. Fla. Agr. Expt. Sta. Bul. 64. 1902.

# A DRILL FOR SEEDING NURSERY ROWS.[1]

C. E. Hill.

In view of the large amount of nursery sowing of field crops done on experiment stations, any implement which will save time and labor and eliminate mixtures of varieties or strains in seeding is of value. A drill which has these advantages has been devised by the writer. The merits claimed for the drill include the following:

1. Greater speed.
2. Greater accuracy.
3. Operation by one man.
4. Elimination of mixtures.
5. Seeding can be done on a windy day.
6. Better germination can be obtained than in hand seeding.

The essential parts of the drill are a funnel into which the seed is dropped by hand at the desired rate; a furrow opener; a tube which carries the seed from the funnel to the furrow opener; and a carriage on which these parts are mounted. The tube is long enough to permit the operator to walk with the body erect while seeding and wide enough to prevent any seed from lodging.

The type of carriage can vary somewhat and yet be satisfactory. A carriage having three wheels, two in front and one in the rear behind the furrow opener, is recommended. This type of carriage will stand without support and can be guided easily.

The front wheels are adjustable on the axle so that when the distance between the rows to be planted is not greater than 1½ feet they can be made to mark the rows by adjusting the distance between the wheels. After sowing the first row the other rows will be spaced properly by running one front wheel on the row previously sown. Rows more than 1½ feet apart can be marked by having an extension rod marker attached to the drill.

The drill is pushed by the body in contact with a padded curved band, attached to the frame of the drill at about the height of one's waist line. It is guided by one hand on the frame in front of the body. The other hand is used in dropping the seed into the funnel.

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

The depth of seeding is regulated by an extension sleeve on the furrow opener.

Seed in envelopes for sowing 100 or more varieties can be carried in a box conveniently placed on the frame of the drill. If a seeding outline is made and the envelopes are arranged in order of sowing, it is not necessary to label the rows until the seeding is completed.

The drill is recommended for sowing short nursery rows of different varieties or strains. With a little practice the rows can be seeded as fast as the drill can be pushed over the ground, as no time is lost in calibrating or cleaning the drill. If the envelope containing the seed is opened in the funnel the possibility of mixtures is eliminated, as the seed is carried directly to the ground in the row to be seeded and none can lodge in the drill. As drilling disturbs the surface soil but little, the seed usually can be drilled into moist ground at a uniform depth, insuring better germination than can be obtained by hand seeding into an open furrow. The drill is suitable for sowing light and fluffy seeds like tall oat grass (*Arrhenatherum elatius*), which will not feed through any of the ordinary types of garden drill. The drill is very simple in construction and can be made at a very low cost.

From these plans a drill essentially the same as the one described was made by Mr. F. J. Schneiderhan at the experiment station, Moro, Oregon, in 1917, from material available on the station. This was found satisfactory for sowing all kinds of seed and was used for all short-row seedings except where definite spacing of the seed was desired. It was also used in sowing long rows of light, fluffy seed that could not be seeded with a Planet Jr. garden drill. In his wheat nursery seeding, Mr. Schneiderhan was able to sow 350 rows 5 feet long per hour. Only 350 rows could be sown in a day by the method formerly used, which was to mark the rows to be sown, open the furrow, drop the seed by hand, and fill the furrows, making in all four operations. At the Moro station this drill was especially liked on account of its elimination of possible mixtures.

# RED ROCK WHEAT AND ROSEN RYE.[1]

FRANK A. SPRAGG.

I wish to take a little of your time this afternoon in discussing some of the new products of the plant breeding work at the Michigan Agricultural Experiment Station.

When I took up the work ten years ago, our highest yielding wheats were white wheats of poor milling and of especially poor baking quality. The problem was to find a red wheat that would at least equal the white wheats in yield. This we are finding in the Red Rock, which originated from an individual plant selected in 1909. This strain was grown in a row in 1910, planted in the regular varietal series (twentieth-acre plat) in the fall of 1911, and distributed in peck lots through county agents in the fall of 1913. The Red Rock is a red wheat of exceptional winter hardiness, high yielding ability, an extra stiff straw, and those characteristics which make a bread of unusual quality.

The Rosen rye, on account of the exceptionally poor competitors, is yielding about twice as much as common rye. It has a shorter, stiffer straw than common rye and much larger heads, which are exceptionally well filled. There are four rows of kernels on every rye head, but the common rye has only scattering kernels along each row. The Rosen has four very nearly complete rows on 99 percent of its heads.

While I am talking about new pedigreed grains I want to mention the Michigan Winter barley. It has not proved as popular as the others, because it apparently does not fit into the rotation as well. It must be sown between August 15 and September 10 in order to produce a root system sufficient to stand the winter and give a good yield the next summer. When planted early on well-prepared, fertile soil, yields as high as 64 bushels to the acre have been reported. It matures before the wheat at a season of the year when the farmers usually need the grain to fatten their hogs. Unfortunately, however, on September 1 almost no land is available for the sowing of a fall crop.

[1] Contribution from the Michigan Agricultural Experiment Station, East Lansing, Mich. Presented by the writer, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

You may have heard of these pedigreed grains to some extent. They are spreading rapidly. Inquiries come to us from nearly every State in the central and eastern portions of the country, extending as far west as New Mexico, where a county agent has purchased the Red Rock wheat for sowing by his farmers this fall.

The distribution of the Rosen rye was started in Michigan in 1912, when about six bushels were distributed, mostly in bushel lots. It seems that we have to distribute to a number of people before we find one that will make the best use of a new thing, and in this case it seems that Carlton Horton, of Albion, was the only man who really took advantage of his opportunity. At that time pedigreed grains in Michigan were new and very little known. Mr. Horton planted his bushel on an acre and the next year got 35 bushels. The man who thrashed the rye and the neighbors who helped became very enthusiastic, so Mr. Horton thought he might easily have sold the rye at $5 a bushel for seed if he had cared to do so. This rye has spread through his own county, Jackson, until now the county agent tells us that almost no common rye is to be found. It has also very nearly replaced the common rye in St. Joseph County. It is estimated that 15,000 acres of Rosen rye were grown in Michigan in 1917 and 250,000 acres sown for the season of 1918.

The distribution of Red Rock wheat began in 1913 by the sending out of peck samples to a number of county agents. I will just mention a few samples and results. The peck that went to Allegan County was sowed on the farm of John Odell, about six miles south of Allegan, on his garden patch in 1914. It produced at the rate of 55 bushels to the acre. He sowed six acres that fall and in 1915 had seed for sale. Though he and County Agent Cook advertised it, the people knew it was a bearded wheat and did not buy until some of the seed had been ground by the local miller, who then became enthusiastic. The favorite trick of the miller was to have two bushels, well cleaned and closely tied in a sack, sitting near so that when a farmer came in the miller invited him to lift the sack. When Mr. Farmer did not lift it at arm's length, he inquired what it was. The miller told him that it was the only wheat grown in Michigan from which he could really make good bread, and on the recommendation of the miller the farmers sowed the seed and kept it pure until in 1917 there was 300 acres of this wheat in Allegan County still pure enough to pass the inspection as pedigreed grain.

The peck sample that went to Kent County became mixed, and though there were 100 acres grown in 1917 it could not be used for

pedigreed grain. The peck sample that went to Newaygo County in 1913 has been cared for by the county agent and in 1916 had been increased to 700 bushels. Four hundred bushels of this went to Kent County to replenish their supply of pure seed. I will just mention one other county. That is Houghton, on the Upper Peninsula, reaching into Lake Superior. Mr. Geismar is county agent there. During the years 1914 and 1915 he acclimated this wheat so that in 1916 it produced a fine crop on the county farm at Houghton. From this seed fields were grown in Houghton, Ontonagon, Marquette, and Delta counties in 1917. Thus, the Red Rock wheat when sown August 15 is proving successful in a spring wheat district.

It is estimated that 4,000 acres of Red Rock wheat were raised in the State in 1917 and that 100,000 acres were sown for the 1918 crop. The demand for this grain has been so great that just at the end of the campaign I received a letter from a farmer who stated that he had failed to obtain any Red Rock for seed and wished to have his name put on the list to receive some next season.

A representative of the Federal Bureau of Markets, Mr. Frank, who was looking up samples of our Michigan wheats in the fall of 1917, saw a large number of samples of Red Rock that had been sent in by the various growers as samples that they guarantee to be just what they were selling. Some of these samples weighed as high as 64 pounds to the bushel, while others had not been allowed to pass the grain inspection because of light weight, smut, or mixtures of other varieties. Mr. Frank obtained nine 2-bushel lots from farmers, ranging from the best to the poorest, for a milling test. He is of the opinion that a special grade will be given to Michigan into which only Red Rock is good enough to fall.

The distribution of our pedigreed grains has been aided greatly by the county agricultural agents, working in connection with the Michigan Crop Improvement Association, of which Mr. J. W. Nicolson is secretary. The members of this association are in general the most up-to-date and progressive farmers in their districts. Selected members of the association receive small samples of new crop varieties from the experiment station. There are also general demonstrations that are offered to members, for which the association must buy the seeds. The members get the benefit of the advertising of the association and the sale of pedigreed seeds when they have any that are acceptable. The expenses of the association are, first, the cost of the seeds for demonstration purposes, except such as are furnished by the plant-breeding work. Because of the

size of the association, this latter is simply a start. Other expenses include the salary and the traveling expenses of the inspector, the advertising in State, county, and agricultural papers, and the printing of seed lists of growers. There is no State aid for this distribution work as there is in Wisconsin. All the expenses must be paid out of the membership and inspection fees, except for the printing of circulars informing the farmers of the benefits derived from the raising of these grains.

The membership fee is $1 a year. If the individual is isolated the inspection of pedigreed grain costs him $10, of which he sends $6 with his application for inspection and pays the remainder when the field is inspected, if it is allowed to pass. If three or more members can be reached in a single day by the inspector, then the inspection fees are reduced by half. The farmer who is really benefitted by the raising of pedigreed grains must sow the new grains on clean land, with a clean drill, out of clean sacks. He must treat the grain for smut. He must pull weeds such as vetch and cockle while in bloom; in fact, he must remove all weeds that can not be screened out after thrashing. He must pull out all mixtures of other grains, such as rye in wheat, and if his wheat contains more than 1 percent of other varieties these must be removed, according to the requirements of 1917. The inspection is going to be more and more strict as the time goes on. The farmer must apply for inspection and entertain the inspector unless he is being taken care of by a county agent.

The farmer must clean his binder and thrasher to prevent mixtures. Fall grains like wheat or rye should be thrashed after oats. Most of the oats will be cleaned out in fanning, while those that remain will be frozen out during the winter. That is one of the advantages Michigan has over the West and South, where spring grains often volunteer. In thrashing oats after wheat, it is well to watch until no more wheat can be seen and then discard a few more bushels to be sure. If the thrashing machine is not cleaned in this way then at least 25 bushels must be discarded in saving seed for sale. Of course, no one stands over the farmer with a stick to make him do this, but these are the general rules that we feel must be obeyed or his grain will not be able to pass the grain inspection. He must fan his grain at home, for if he sends it to an elevator he gets it mixed beyond redemption. He must remove all weed seeds, all smut balls, and shriveled kernels that will not produce thrifty plants. Then he must send the secretary of the association a peck

sample of the grain just as he expects to sell it. If this grain is to pass the second inspection it must be free from weeds, up to standard weight, and contain less than 1 percent of mixture of other varieties. If his grain is passed he receives the association's shipping tags and report cards. His name is put on printed lists of growers who have seed for sale. The association does the advertising and those who inquire as to where they can purchase good pedigreed grains are sent these printed lists. The growers also certify on the back of the shipping tags. For instance, if it is Red Rock, "The wheat in this bag is Red Rock; it grew on a field inspected by an agent of the association; it conforms to the State seed law, and it conforms to sample submitted to the association for inspection." This certification is the purchaser's guarantee that the seed is as it is supposed to be, and is binding upon the grower to the extent that he must refund the money or make it right. Several did this last fall. For instance, one grower in Allegan County refunded $1 a bushel on some seed that had evidently not been recleaned.

## THE IDENTIFICATION OF VARIETIES OF OATS IN NEW YORK.[1]

E. G. MONTGOMERY.

During the summer of 1917, Mr. George Stewart, one of the graduate students in farm crops at the New York State College of Agriculture, undertook as a part of his graduate work to make a practical test of Dr. Etheridge's key to oat varieties[2] under field conditions. Samples of oats were collected from New York State seedsmen and grown in the garden for identification, and also oats growing in fields were examined and identified. In addition, varieties growing at two experiment stations were also examined. Some of the results as worked out by Mr. Stewart are here given.

The varieties offered by certain seedsmen and their identification were as follows:

[1] Contribution from the Department of Farm Crops of the College of Agriculture, Cornell University, Ithaca, New York. Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Etheridge, W. C. A classification of the varieties of cultivated oats. N. Y. (Cornell Univ.) Agr. Expt. Sta. Memoir 10, 1916.

| Seedsman's name. | Identification according to key. |
|---|---|
| Seedsman A | |
| Winter or Turf | Winter Turf. |
| Imported Clydesdale | Swedish Select. |
| Early Newmarket | Do. |
| Swedish Select | Do. |
| Long's White Tartar | Tartar King. |
| Imported Black Tartarian | Black Tartarian. |
| American Clydesdale | Swedish Select. |
| Probsteier | Do. |
| Long's Storm King | Storm King. |
| White Russian | Storm King or Tartar King. |
| Seedsman B | |
| Tartar King | Tartar King. |
| Canada Cluster | Swedish Select and Storm King. |
| Seedsman C | |
| Michigan | Lincoln and Belyak. |
| Seedsman D | |
| Northern Wonder | Swedish Select. |
| Seedsman E | |
| Alberta Cluster | Swedish Select. |
| Seedsman F | |
| Golden Fleece | Swedish Select and Storm King. |
| Bumper Crop | Storm King and Swedish Select. |
| Long's White Tartar | Storm King and Swedish Select. |
| Seedsman G | |
| Alberta Cluster | Swedish Select. |
| Seedsman H | |
| Heavy Weight | Swedish Select. |
| Twentieth Century | Belyak. |
| Seedsman I | |
| Swedish Select | Belyak. |

Where two varieties were identified, the dominant type is named first. Out of 10 varieties offered by Seedsman A, 5 appeared to be straight Swedish Select, if the identification is correct. When this identification was presented to the seedsman, he stated that four of the varieties identified as Swedish Select were imported from England, which would indicate that in Europe also they are using several names for what appears to be the same variety. Of course, there may be differences in adaptation or quality not discernible in a botanical examination, but at least to all outward appearances the varieties are identical.

Of the 22 varieties listed above, 11 are of Swedish Select type and 2 more contain an admixture of Swedish Select. This would indicate that this type has been found best for the State.

The varieties grown at one experiment station, together with the identifications found, were as follows:

| Experiment station name. | Identification according to key. |
|---|---|
| 1. Silvermine | Silvermine. |
| 2. White Russian | Swedish Select. |
| 3. Corn Belt | Lincoln. |
| 4. President | Lincoln and Swedish Select. |
| 5. Wideawake | Irish Victor. |
| 6. Napoleon | Swedish Select and Lincoln. |
| 7. Siberian | Swedish Select, Lincoln and June. |
| 8. Burt | Burt. |
| 9. White Probsteier | Lincoln and Swedish Select. |
| 10. Golden Fleece | Swedish Select. |
| 11. White Plume | Storm King. |
| 12. Joanette | Joanette. |
| 13. Canadian Side | Storm King, Lincoln and Belyak. |
| 14. Hvitling | Lincoln and Belyak. |
| 15. Lincoln | Lincoln and Silvermine. |
| 16. Sixty Day | Kherson. |
| 17. Welcome | Silvermine or Scottish Chief. |
| 18. Czar of Russia | Swedish Select, Lincoln and Silvermine. |
| 19. Black Mogul | Black Norway (?) |
| 20. Clydesdale | Silvermine and June. |
| 21. Big Four | Belyak, Silvermine, and June. |
| 22. Seizure | Green Mountain. |
| 23. Alaska | Lincoln, Belyak, and June. |
| 24. American Banner | Belyak and Lincoln. |
| 25. Morganfeller | Silvermine, Lincoln, and Belyak. |
| 26. Swedish Select | Swedish Select. |
| 27. Long's White Tartar | Storm King. |
| 28. Golden Rain | Golden Drop. |
| 29. Sparrowbill | White Tartar and Storm King. |
| 30. Improved American | Lincoln and Swedish Select. |
| 31. Beardless Probsteier | Awnless Probsteier. |
| 32. Green Mountain | Lincoln. |
| 33. Ellwood | Belyak and Silvermine or Scottish Chief. |
| 34. Victory | Lincoln and Silvermine. |
| 35. Early Champion | Irish Victor. |
| 36. Sensation | Lincoln, Swedish Select, and Early Gothland. |
| 37. Twentieth Century | Lincoln, Swedish Select, and C. I. 602. |
| 38. Storm King | Storm King. |
| 39. White Ligowa | Swedish Select. |
| 40. Detmer's New Bumper | Storm King. |

The above list is given to illustrate the situation that probably exists at all of the experiment stations where varietal tests are under way and emphasizes what has heretofore been pointed out, the need of a careful study of varietal nomenclature and the standardization of names.

In order to get some idea in regard to the type of oats grown by

New York State farmers, examination was made of a strip of country across the State from north to south, which is believed to be fairly representative. In all, 418 fields were examined with the results shown in Table 1.

TABLE 1.—*Number of farms on which certain varieties of oats are grown in Cortland, Tioga, Cayuga, Tompkins and Ontario counties, New York.*

| Variety. | Virgil, Cortland Co. | Owego, Tioga Co. | Auburn, Cayuga Co. | Moravia, Cayuga Co. | Ithaca to Dryden, Tompkins Co. | Ithaca to Trumansburg, Tompkins Co. | Western Ontario Co. | Eastern Ontario Co. | Total |
|---|---|---|---|---|---|---|---|---|---|
| Lincoln.......... | 7 | 15 | 15 | 17 | 7 | 31 | 18 | 8 | 118 |
| Swedish Select ... | 11 | 6 | 10 | 20 | 9 | 15 | 30 | 9 | 110 |
| Belyak.......... | 3 | 3 | 5 | 1 | 3 | 20 | 9 | 3 | 47 |
| Silvermine....... | 7 | 8 | 3 | 1 | 8 | 5 | 17 | 8 | 57 |
| Canadian........ | 4 | | 14 | 7 | 3 | | | | 28 |
| Storm King...... | 4 | 10 | 4 | 1 | 2 | 3 | 8 | 2 | 34 |
| Sparrowbill..... | | | 1 | 3 | | | | | 4 |
| June............ | | 1 | | 1 | | | | 1 | 3 |
| Old Island Black . | | | | 1 | | | | | 1 |
| Irish Victor...... | | | 2 | | 1 | | 1 | 3 | 7 |
| Tobolsk......... | | | 1 | | 1 | | | | 2 |
| Danish Island... | | | 3 | | | | | | 3 |
| White Tartar .... | | | | | | 2 | | 2 | 4 |
| Total ......... | 36 | 43 | 58 | 52 | 34 | 76 | 83 | 34 | 418 |

The figures given in Table 1 show the following percentages of the different oat varieties in central New York State:

| Variety. | Per Cent. |
|---|---|
| Lincoln .............................................. | 28.2 |
| Swedish Select ...................................... | 26.3 |
| Silvermine ........................................... | 13.6 |
| Belyak ................................................. | 11.3 |
| Storm King ........................................... | 8.1 |
| Canadian ............................................. | 6.7 |
| All others ............................................ | 5.8 |
| | 100.0 |

The summaries show that 79.4 percent of the oats were identified as Lincoln, Swedish Select, Belyak, and Silvermine. These varieties are very similar and can hardly be distinguished from each other except by a trained observer. The indications are that long experience of both the seedsmen and farmers have shown this type to be the best adapted to the State.

# ORIGIN OF THE GEORGIA AND ALABAMA VARIETIES OF VELVET BEAN.[1]

H. S. COE.

For many years the Florida velvet bean (*Stizolobium deeringianum* Bort) has been grown in Florida and the extreme southern part of the Gulf States as a soil-improving crop and for grazing. In other portions of the South the value of this plant was limited, as it required a frost-free season of eight to nine months to nature. Even though only a portion of the pods usually matured in the southern half of the Gulf States, many farmers valued this crop so highly for grazing and for soil improvement that they planted it annually.

As the United States Department of Agriculture recognized the value of an early-maturing velvet bean which would produce winter grazing equal to that of the Florida variety and which would mature in most parts of the cotton belt, a careful search was made for such a plant in other countries. The Chinese velvet bean was introduced from Tehwa, China, and the Yokohama velvet bean from Yokohama, Japan. Both of these plants mature earlier than the Florida variety but their pods have the undesirable characters of splitting and shattering the seed when mature. The Chinese variety is superior to the Florida for the southern portion of the Gulf States, but it rarely matures in the northern part of the cotton belt. The Yokohama matures in about 120 days, but it produces a small vine growth and most of the pods are formed so close to the ground that in a relatively short time they decay. However, before either of these species was introduced, two early maturing mutants of *Stizolobium deeringianum* were found in southern Georgia, although they were unknown to the public for several years.

In the spring of 1906, Mr. Clyde Chapman of Sumner, Ga., planted a field of corn and Florida velvet beans. The following August, several hills of mature beans were found in this field. The seed collected from these early-maturing plants was planted in corn the following year and early plants were produced, similar to those found the previous year. A small quantity of the seed grown in 1907 was distributed to several of Mr. Chapman's neighbors, but so far as

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

known none of this seed was sent out of this immediate section prior to 1912, with the exception of one lot sent to Schley County, Ga., in the spring of 1909. The seed of the Florida velvet bean planted in the spring of 1906 was obtained from Mr. Z. C. Allison, of Sumner, Ga., a relative of Mr. Chapman's. Three or four years prior to this date Mr. Allison obtained seed of this particular strain from a field in Schley County, Ga., and each year enough seed matured on his farm for seeding the following spring.

The first early-maturing plants noted by Mr. Chapman made a small vine growth, matured their first pods in 90 to 100 days from planting, and produced seed which, according to Mr. Chapman, was somewhat paler and slightly smaller than the seed of the Florida velvet bean. From the first the plants of this early-maturing variety came true to type.

Another mutant of the Florida velvet bean was found by Mr. R. W. Miller, of Broxton, Ga., in August, 1908, in a field planted to corn and Florida velvet beans. The velvet bean seed planted in this field was grown in Florida. The seed of these early-maturing plants was sown in 1909 and, according to Mr. J. D. Harrell, of Douglas, Ga., a relative of Mr. Miller's, the plants came true to type. Mr. Harrell obtained some seed from Mr. Miller in the spring of 1910 and that year harvested 15 bushels. So far as known, the seed of this mutant was not generally distributed by Mr. Miller or Mr. Harrell, but Mr. W. A. Clark, of Jacksonville, Ga., obtained seed from Mr. Harrell in 1913, and later sold seed of this variety under the name of "Clark's velvet bean." This bean, so far as can be determined, is identical with the one found by Mr. Chapman. In investigating the origin of this mutant, not the slightest evidence was found to indicate that the early-maturing plants found by Mr. Miller could have been produced from seed grown by Mr. Chapman.

A third mutant of the Florida velvet bean was found by Mr. H. L. Blount, of Flomaton, Ala. Mr. Blount, who had grown velvet beans as a grazing crop for at least fifteen years, obtained seed from Florida, which he planted with corn in the spring of 1911. In a sandy gap in this field, one plant was observed which bloomed much earlier than any of the others. By October 20, and before frost, all of the seed on this plant was matured and the plant was dead. About 1½ pints of seed were collected from it. This seed was planted along a fence row in 1912, and that fall several bushels of seed were harvested. In the spring of 1913, 50 to 60 packages of this seed, varying in size from one half pint to one quart, were

sent to farmers in Alabama, Mississippi, and Georgia for trial, and the remainder of the 1912 crop was planted in corn on Mr. Blount's farm. In 1914 seed of this variety was sold to a number of Alabama farmers and to the Alabama Agricultural Experiment Station. Mr. Blount stated that as soon as he found the early-maturing plant he wrote to the person in Florida from whom he purchased his seed, asking him if he had observed early-maturing plants in his fields. The reply stated that an early-maturing velvet bean had

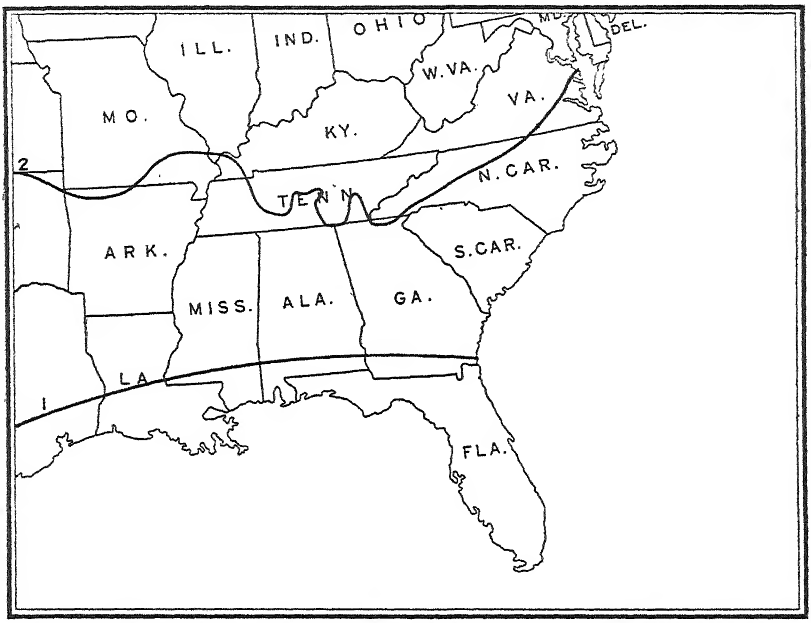


FIG. 25. Map showing the extension of the velvet bean area by the introduction and discovery of early maturing varieties. The Florida velvet bean will seldom mature fully north of line No. 1, while the Georgia variety will mature south of line No. 2.

never been observed by the writer. The early-maturing plant found in 1911 made a somewhat smaller vine growth and produced slightly smaller and somewhat paler seed than the Florida velvet bean, but it made a larger vine growth than the early-maturing varieties found by Mr. Chapmen and Mr. Miller. This variety matured fully in 170 to 180 days, or about two months earlier than the Florida velvet bean. It is known as the Alabama velvet bean.

The N. L. Willet Seed Company, of Augusta, Ga., the Office of Forage-Crop Investigations, the Office of Extension Work in the

South, and Mr. Clifford Grubbs, manager of the Farmers' Produce Exchange, of Sylvester, Ga., were largely responsible for the general distribution of the early variety discovered by Mr. Chapman. Mr. Willet purchased about 200 bushels of seed of this variety from a neighbor of Mr. Chapman's in the fall of 1914. This seed was sold to the seed trade in the spring of 1915 under the name of "Hundred-Day Speckled." Twenty bushels was purchased from the N. L. Willet Seed Company by the Office of Forage-Crop Investigations in the spring of 1915 and distributed in small packages in different sections of all of the Southern States in 1915 and 1916. The Office of Extension Work in the South purchased a quantity of seed of this variety at Atmore, Ala., in the spring of 1915. Some of this seed was sent to each county agent in Alabama and Mississippi, and to a few agents in Louisiana, eastern Texas, and South Carolina for planting on demonstration farms. Mr. Clifford Grubbs shipped to many points in the South the surplus grown by the farmers living in the vicinity of Sumner. The first shipments were made in 1913 and about 25 bushels were sold. In 1914 approximately 100 bushels and in 1915, 500 bushels were distributed in this manner.

The Office of Forage-Crop Investigations has suggested that the name "Georgia" be used in preference to "Hundred-Day Speckled" because the variety was first discovered in Georgia and further because it does not mature in 100 days, as the name "Hundred-Day Speckled" indicates. The first few pods may mature in that time but it usually requires 120 to 130 days for the entire crop to ripen.

It is probable that early maturing mutants of *Stizolobium deeringianum* have appeared elsewhere, but, if observed and isolated, no records have been obtained.

As both the Georgia and Alabama varieties have been distributed to all parts of the South, it is impossible to say in what percentage each contributed to the 1917 crop. As the Georgia variety was more generally distributed in 1915 and as much of the seed grown that year was sold for seeding purposes, it is assumed that the acreage of the Georgia was much larger than that of the Alabama in 1916 and 1917. It is believed that the Alabama variety will be planted most extensively in the southern portion of the cotton belt and the Georgia variety in the northern portion on account of the time required for each to mature. The Alabama variety makes a larger growth and therefore should yield more heavily than the Georgia in sections where the growing season is long enough for it to mature.

By the discovery and distribution of these early-maturing varieties the culture of velvet beans has been greatly popularized and has extended to the northern limits of the cotton belt (fig. 25). Not only has the area of adaptation been largely increased but the acreage of velvet beans has increased from less than 1,000,000 to over 5,000,000 in the past three years (fig. 26). The acreage in 1917 was 119 percent greater than in 1916. The direct and indirect value of this enormously increased acreage of a vigorous-growing legume will be a determining factor in improving the agricultural industry of the South, as the large quantity of nutritious feed produced by this crop at a low cost will stimulate the production of livestock. The net cash

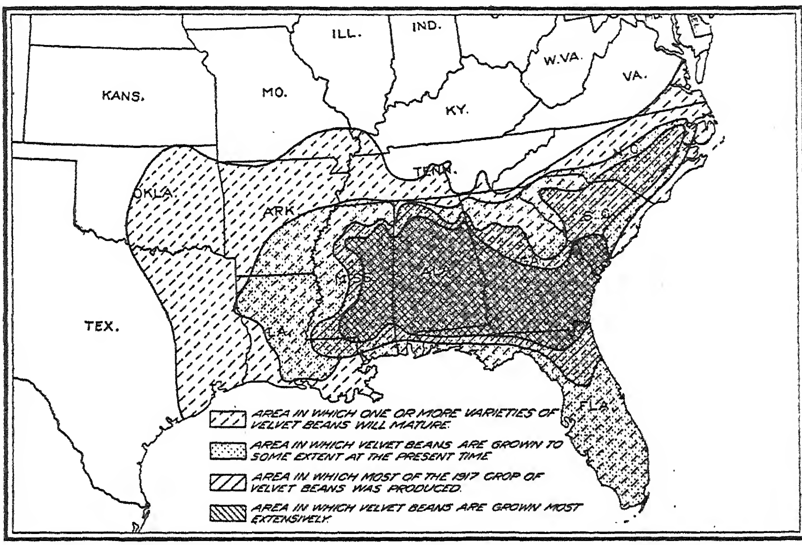


FIG. 26. Map showing the distribution of velvet beans.

value of the early-maturing velvet beans produced in corn was more than $20,000,000 in 1917. To the net cash value of the beans and pods may be added the value of the increased yields of subsequent crops, as the vines will be plowed under or pastured and when pastured but little of their fertilizing value is removed from the field. Experiments conducted by different experiment stations show that velvet beans are superior to cowpeas, beggarweeds, or soybeans for improving the soil. Therefore, it is believed that the value of the vines and roots of the 1917 crop for this purpose is at least twice as great as the cash value of the beans and pods.

# THE VALUE OF BLUE LITMUS PAPER FROM DIFFERENT SOURCES AS A TEST FOR SOIL ACIDITY.[1]

P. E. KARRAKER.

Many workers in soils, through publications and otherwise, advise that farmers use the well-known blue litmus paper test as a qualitative field determination for soil acidity. A smaller number express doubt as to any great value attached to this test, especially in the hands of farmers, and some few think that the farmer should leave the test entirely alone. Barlow[2] has gotten together a number of

In the soils laboratory of the agronomy department of the Kentucky station it is the custom to use the blue litmus paper test to get an initial idea as to the reaction of the soil before employing the quantitative lime-water determination, and to a limited extent the test is used independently when only qualitative information is desired.

Kalbaum's blue litmus paper, a stock of which had been on hand since the fall of 1915, was used in this work. This paper is very sensitive and apparently has nearly always given accurate qualitative results. In addition it has afforded some information in a quantitative way. Recently, blue litmus paper tests were made in 32 soils. Afterwards, occasion arose to determine the limestone requirement of these soils by the Hopkins and also by the Veitch lime-water methods. In but one or possibly two instances was the qualitative information afforded by the litmus paper test at fault.

Lately in connection with the preparation of a practical bulletin on liming land, the question arose as to the proper time to leave the blue litmus paper strips in the soil. Reference to the literature showed a considerable diversity of direction on this point. For instance, Whitson and Weir[3] advise that the paper be left in 5 minutes; Abbott[4] about 10 minutes; Schollenberger[5] about half an hour; and Barker and Baer[6] as much as half an hour.

[1] Contribution from the Agricultural Experiment Station, University of Kentucky, Lexington, Ky. Received for publication December 13, 1917.

*In* Jour. Amer. Soc. Agron., 8: 26, 27. 1916.

[2] Barlow, J. T. Soil acidity and the litmus paper method for its detection.

these published opinions.

[3] Whitson, R. A., and Weir, W. W. Soil acidity and liming. Wis. Agr. Expt. Sta. Bul. 230, p. 9. 1913.

[4] Abbott, John B. Liming the soil. Ind. (Purdue Univ.) Agr. Expt. Sta. Circ. 33, p. 12. 1912.

[5] Schollenberger, C. J. Acid soils and soil acidity. *In* Ohio Agr. Expt. Sta. Monthly Bul., p. 33. October, 1917.

[6] Barker, J. F., and Baer, W. W. Ground limestone for use in New York State. N. Y. State Agr. Expt. Sta. (Geneva) Bul. 430, p. 29.

It has been the custom in this laboratory to leave the litmus paper in the saturated soil only 5 to 10 minutes, usually only 5 minutes. In nearly all cases a distinct pink and often the maximum pink occurs in this time when the soil is acid. The color change occurring in a much longer period, 30 minutes or more, is not considered as trustworthy as that from the shorter period, as there is a tendency for a pink color to develop in this longer period whether the soil is acid or not.

Obviously the length of time that the paper should remain in the soil will depend on its sensitiveness. Litmus paper from different sources varies much in this respect. The worker is very likely to recommend the length of time best adapted to the paper with which he is familiar. If it were not for the tendency of a pink color to develop in time, particularly in heavy soils, even in the absence of an acid condition, a maximum time could be prescribed which would enable the color change to occur with litmus paper of all grades of sensitiveness. The fact that litmus paper from different sources does vary in sensitiveness and that a maximum time can not be prescribed on account of danger of appearance of a pink color during this time in the case of more sensitive paper irrespective of an acid soil condition, is on the surface a valid objection to the general use of litmus paper as a test for soil acidity.

To obtain some information as to the color change in acid soils of blue litmus paper from different sources, samples of the paper were gotten from different departments in the experiment station. Litmus paper from five different sources was thus secured. Requests were also made of a number of druggists through the State for samples of their blue litmus paper and samples obtained from ten of them. In a number of cases the paper was not in stock. These samples were compared with the Kalbaum's paper by testing in a soil which had a limestone requirement of 2,912 pounds as determined by the lime-water method.

The tests were made very much after the method used in laboratories of the Misouri station by laying the litmus paper slips on a watch glass and forcing the soil after it had been made into a mud ball well up against them by means of a second watch glass. This leaves the soil and litmus paper between two watch glasses with the paper directly against one glass so that the color change can be observed at any time.

Under these conditions, the Kalbaum's paper showed a distinct pink in 2 minutes, and the maximum pink color was reached in about 5

minutes. Of the five experiment station papers, two were found to be about as sensitive as Kalbaum's, one required an hour to show a slight pink, and two at the close of two hours showed very little or no pink at all.

The druggists' samples were compared with the Kalbaum's in the same way. In 5 minutes, as usual, the Kalbaum's paper gave a good pink. Of the druggists' papers, one gave a good pink and 3 others a slight pink. In 30 minutes, slight pink appeared in 3 more. At the end of two hours, a good pink was present in 4 of the druggists' papers, a fair amount of pink in 3, and a slight pink in one. In paper from 2 of these samples no pink color appeared at all.

When these druggists' papers together with the Kalbaum's were placed in one thousandth normal hydrochloric acid solution, the following color changes appeared. The maximum amount of pink appeared in the Kalbaum's paper in a half minute, and in the druggists' papers as follows: In one, in 1.5 minutes; in one, in 5 minutes; in two, in 8 minutes; in two, in 9 minutes; in one, in 15 minutes, in one, in 30 minutes; and in two, no pink color appeared at all. These latter two gave pink color in a strong acid solution. In the main, the sensitiveness of the papers as determined by the acid solution checked up closely with that observed in the soil.

Tests in the soil were made with a few neutral litmus papers from different sources, but the color change is not distinct enough to make the use of this paper advisable.

Tests were also made with the Kalbaum's blue litmus paper in a few soils of limestone origin which still contained limestone as shown by vigorous effervescence with hydrochloric acid, to determine whether a pink color would appear under these conditions. In a heavy subsoil a slight pink appeared at the end of 30 minutes; however, it was not permanent. In a lighter surface soil the paper always remained blue. There is no doubt, however, of the tendency for sensitive blue litmus paper to develop a pink color in soils of high colloidal content in the absence of an acid condition.

In part as a result of this limited study, it is thought inadvisable to recommend the blue litmus paper test to farmers as a means of testing for soil acidity. In the hands of an operator who is familiar with the paper he is using and knows what color changes to expect under various conditions, the test is a good qualitative one for soil acidity and in addition gives some information in a quantitative way, but for general use it can not be considered reliable and may give results which are entirely misleading.

# PRIMITIVE METHODS OF MAIZE SEED PREPARATION.[1]

H. HOWARD BIGGAR.

The word "corn" in the Indian language has many forms. In the Sioux it is "wagamaza," in the Omaha it is "wahaba," in the Gros Ventre it is "holiati," in the Mandan it is "khati," while the Arikara calls it "nicissee." The word is one of the most important in the tribal vocabulary, since corn for generations was the main and often the only food plant.

In an investigation covering 15 Indian reservations in Minnesota, North Dakota, South Dakota, Nebraska, Montana and Manitoba, the writer was much impressed by the agricultural practices of the Indians in connection with their corn production. None of these practices are of more interest than the preparation of seed.

The Indian designated time by referring to natural phenomena. Seed was prepared and corn planted when the wild turnips began to bloom, when the grass began to become green, when plums, wild grapes, or juneberries began to blossom, when the leaves began to uncurl, or when the first prairie flowers began to bloom. Superstition and suggestive magic played an important part in seed preparation. Red Bear, an Arikara of the Fort Berthold reservation, informed me that the oldest woman of each family was usually intrusted with this work and that it was partly a secret process and almost a sacred one. It was Red Bear's opinion that since the old methods had been discontinued the cornfields of the Indians produced lower yields and the plants were more susceptible to insects and to plant diseases.

Various standards were used as the basis of seed selection. Many of the Indians have told me that moldy cobs on ears in the fall were very undesirable. For the most part, well-filled tips were sought as well as straight rows of kernels. The tip and the butt kernels were discarded and the middle kernels used for seed, the explanation being that these were better producers. Seed ears were braided together by the husks every fall, the braids being about 5 feet long.

Indian informants on the Crow Creek, Lower Brule, Rosebud, Yankton, Standing Rock, Fort Berthold, Fort Totten, and Red Lake reservations, representing tribes of the Sioux, Gros Ventre, Arikara,

[1] Contribution from the Office of Corn Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication February 2, 1918.

and Chippewa Indians, stated that it was always the custom to sprout the corn kernels previous to planting. The sprouting had a two-fold object, (1) to insure the plants coming up more quickly and (2) to insure a good stand of plants, since kernels not sprouting were at once discarded.

In the Red Lake reservation country of northern Minnesota, the Chippewa Indians had their fields bordering the lake and entirely around it. The lake country was densely wooded and hence use was made of moss in sprouting. Previous to planting, a box was filled with moss and kernels of corn placed in the moss. The whole was soaked for a time and then set in a warm place until the kernels sprouted. Dead kernels were thrown out and the sprouted ones were planted. Some tribes placed kernels in small sacks, soaked the sacks in water, and then hung them in a warm room to germinate. Others made willow baskets, filled them with kernels of corn, poured water through the corn, and then placed the baskets in a warm place.

Red Horse of the Yankton Reservation was the first to tell the writer of the use of the ground plum (*Astragalus caryocarpus*) in connection with the sprouting of seed corn. Later, members of other tribes corroborated his story. It is a custom among some tribes to soak the fruits of the ground plum in the same water in which the seed corn was soaked. The ground plum is the well-known prairie legume with a habitat ranging from Saskatchewan to Texas. Dr. M. R. Gilmore, State historian of North Dakota, believes that as the ground plum is prolific, bearing many fruits, the Indians thought its use would make the corn more productive. This explanation is in line with Indian beliefs. The Omahas in Nebraska placed the shell of a turtle in the water with the corn, believing that, as turtles eat insects, the use of the shell would aid in keeping the corn plants free from insect damage.

While the writer was visiting the Crow Creek Indian Reservation in South Dakota, Medicine Crow, Kill Dead, and Seeking Land gave the first information regarding what might almost be called a primitive ragdoll seed tester. Subsequently William Bean of the Yankton Reservation in South Dakota and Matokikta and Little Bull of the Fort Totten Reservation in North Dakota confirmed their statements. The main part of this primitive tester was the stem of the slender nettle, *Urtica gracilis*. The leaves of this nettle are sparingly armed with stinging hairs. After describing the plant, Medicine Crow took me into the near-by woods and showed me a clump of them. Large patches were also seen in the vicinity of Devil's Lake, N. Dak., on the

Fort Totten reservation. The Sioux Indian name for this nettle is "asbehu" or itch weed.

The slender nettle was used in the following manner. When the time for planting corn was at hand, quantities of the nettle were gathered. They were then piled up in a sort of mat and on this mat the kernels were placed. The mat of nettles was then rolled up so that it made a cylindrical bundle with the corn kernels on the inside. The bundle was tied round with strings cut from buffalo hide and then immersed in water. After soaking for a day or more, the bundle was removed, wrapped in a buffalo skin or some other covering, and kept warm. In a few days the kernels sprouted and when the sprouts were a quarter of an inch or more long they were planted. Kernels not sprouting or showing swollen germs were at once discarded. The slender nettle was used for this purpose instead of some other prairie plant because it was the first plant to reach any considerable height by corn-planting time. Further, the fact that the plant was protected with stinging hairs gave the Indian the superstitious idea that corn germinated with it would be protected from plant enemies during the growing season.

At the South Dakota State Fair at Huron in September, 1917, the Crow Creek Indian Agency exhibit included a nettle tester in which corn was being germinated. These testers have been used by the Indians for at least seventy-five years.

The principal corn grown by the Indians of the Middle West was the soft or flour corn, *Zea amylacea*. This type absorbs water more readily than the dent or flint types, as shown by the following experiment. One hundred grams of each variety were placed between wet bleached muslin and reweighed after 22 hours. The blue flour corn absorbed 18.0 percent of water; Reid yellow dent absorbed 13.5 percent; and U. S. Selection No. 193, a flint corn, only 6.6 percent.

## THE TIME AT WHICH COTTON USES THE MOST MOISTURE.[1]

C. K. McClelland.

It has long been recognized that cotton can be produced with less water than is required for crops of corn and oats. Not only is this true, but apparently there is a great difference in the stage of growth when these crops require the maximum amounts of water. A dry

[1] Contribution from the Georgia Agricultural Experiment Station, Experiment, Ga. Presented by the author at the second annual meeting of the Association of Southern Agricultural Workers, New Orleans, La., in January, 1917. Received for publication February 10, 1918.

time occurring when corn or oats are filling and ripening noticeably reduces the yield, but with cotton a dry time during the maturing (opening) of the crop is to be desired. Probably, however, there is an analogy between the processes of growth which are taking place in the cotton and in the grains during the periods when each is using large amounts of water; that is, the blooming and boll-filling period of cotton rather than the opening should be considered the same period of growth as the blooming and head-filling or ear-filling periods of the grains. At this period of growth a dry time is equally as disastrous with cotton as with the grains, the effects being shown largely in the shedding of the squares or newly set bolls.

TABLE 1.—*Liters of water applied weekly from July to September, inclusive, to individual cotton plants grown in potometers in 1915, with the percentage of saturation at which each was maintained.*

| Plant No. | Saturation, percent. | First period. | | | Second period. | | | | | | Third period. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Week in July. | | | 4th week July | Week in August. | | | | 1st week Sept. | Week in Sept. | |
| | | 1st. | 2d. | 3d. | | 1st. | 2d. | 3d. | 4th. | | 2d. | 3d. |
| 17 | 60 | | | 3.5 | 12.8 | 6.6 | 19.6 | 19.9 | 31.0 | 15.5 | 26.5 | 19.9 |
| 24 | 60 | 3.5 | 3.5 | 28.0 | 28.7 | 35.4 | 24.0 | 24.3 | 42.0 | 11.0 | 26.5 | 22.1 |
| 6 | 75 | | 5.3 | 15.7 | 19.9 | 26.5 | 37.6 | 35.4 | 33.2 | 19.9 | 26.5 | 13.2 |
| 18 | 75 | 3.5 | 7.0 | 14.0 | 23.4 | 44.2 | 26.5 | 31.0 | 37.6 | 17.7 | 19.9 | 15.5 |
| 29 | 75 | | 1.8 | 14.0 | 13.2 | 22.1 | 28.7 | 26.5 | 35.4 | 11.0 | 26.5 | 22.1 |
| 14 | 90 | 1.8 | 21.0 | 22.8 | 39.8 | 50.8 | 28.7 | 28.7 | 28.7 | 6.6 | 28.7 | 15.5 |
| 23 | 90 | 1.8 | 3.5 | 17.5 | 24.3 | 42.0 | 28.7 | 28.7 | 26.5 | 6.6 | 28.7 | 4.4 |
| 22 | 30–60–90 | 1.8 | 1.8 | 14.0 | 18.4 | 15.5 | 15.5 | 31.0 | 22.1 | 13.2 | 33.2 | 24.3 |
| 7 | 90–30–60 | 3.5 | 17.5 | 15.7 | 6.6 | 13.2 | 2.2 | 22.1 | 11.0 | 6.6 | 15.5 | 8.8 |
| 30 | 90–30–60 | 3.5 | 15.5 | 24.5 | 6.6 | 28.7 | 24.3 | 24.3 | 15.5 | 4.4 | 31.0 | 4.4 |
| Totals.......... | | 19.4 | 77.1 | 169.7 | 193.7 | 285.0 | 232.8 | 271.9 | 293.0 | 112.5 | 263.0 | 150.2 |

Blooming records taken in different years may show a seasonal variation and naturally there will be some variation between varieties and likewise between individuals. In general, however, records of blooming will give a fairly good index to the time of year when the filling process begins. The time when the blooms are coming out most rapidly and the time when the plants are using the most moisture seem to be correlated. In experiments to determine the water requirements of cotton conducted at the Georgia station in 1915 and 1916, plants were grown in potometers and the quantity of water applied at different periods recorded. Table 1 shows the liters of water applied to the individual plants by weeks during July, August, and September. The number of blooms appearing each week on each individual and the number of blooms appearing on plants under field conditions each week are recorded in Table 2.

TABLE 2.—*Number of flowers opening weekly on individual cotton plants in potometers in 1915, with the number on 18 plants in the field.*

| Plant No. | Total number of blooms. | Week in July. | | Week in August. | | | | First week Sept. |
|---|---|---|---|---|---|---|---|---|
| | | Third. | Fourth. | First. | Second. | Third. | Fourth. | |
| 24 | 84 | | 6 | 10 | 21 | 24 | 20 | 3 |
| 18 | 67 | 1 | 5 | 10 | 18 | 18 | 13 | 2 |
| 14 | 67 | 2 | 10 | 11 | 18 | 17 | 9 | |
| 22 | 47 | | 6 | 5 | 10 | 9 | 11 | 3 |
| 7 | 35 | 3 | 9 | 12 | 9 | 1 | 1 | |
| Total ............ | 300 | 6 | 36 | 48 | 76 | 69 | 54 | 8 |
| 18 field plants...... | 327 | | 129 | 118 | 80 | | | |

Table 2 shows that the plants in the potometers began blooming the third week in July, increasing until the second week in August, and then decreasing. The record of 18 plants in the field showed that the greater number of blooms appeared there during the last week in July. This difference is due primarily to the fact that the plants in the potometers were from seed planted rather later than those in the field and even in most cases from replantings. The replanting was due to the destruction of the first plants by girdling with plastic clay in attempts to prevent evaporation and the penetration of rain water into the cans. The cotton plant is very tender in its earlier stages and is easily damaged by such treatment. If the supply of moisture remains constant, blooming may be delayed. This statement is perhaps better made in the reverse order, that is, the checking of the supply of moisture induces earlier blooming. In the fields the supply was checked, there being no heavy rains from July 4 to August 16. In the cans, the supply was constant except as noted. With plants 22, 7, and 30 the saturation was changed as shown in the table during each period. Plant No. 7, where the moisture was reduced from 90 percent to 30 percent, produced the maximum number of blooms one week earlier than the average. Plant No. 22 bloomed later than the average due at least in part to the accidental topping of the plant.

Most of the plants were grown in soils where the saturation was kept constant or nearly so, semiweekly weighings being made to show the loss of water and the depreciation below the desired content, after which water was added to bring the saturation to the desired point or a little above. Where the saturation was varied, the change was made when the squares began to form and when the blooming period was nearly over. It will be noted that the plants used large amounts of water during the entire second period and well into the third. On account of the breaking of the balances with which the weighings were made,

no records were obtained after the third week in September. The second period covered nearly the entire blooming period of the plants.

Records similar to those shown in Tables 1 and 2 for 1915 are presented in Tables 3 and 4 for the experiments conducted in 1916.

TABLE 3.—*Liters of water applied weekly from July 25 to October 7, to individual cotton plants grown in potometers in 1916, with the percentage of saturation at which each was maintained.*

| Plant No. | Saturation, percent. | Week ending | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July 25. | Aug. 8. | Aug. 14. | Aug. 22. | Aug. 28. | Sept. 4. | Sept. 12. | Sept 19. | Sept. 25. | Oct. 7. |
| 4 | 45 | 2.25 | 9.00 | 13.50 | 11.25 | 13.50 | 6.75 | 11.25 | | 6.75 | 4.50 |
| 11 | 45 | | 6.75 | 11.25 | 11.25 | 13.50 | 6.75 | 11.25 | | 9.00 | 4.50 |
| 17 | 45 | | 2.25 | 9.00 | 9.00 | 13.50 | 2.25 | 11.25 | | 9.00 | 4.50 |
| 36 | 45 | | 4.50 | 13.50 | 9.00 | 13.50 | 4.50 | 11.25 | 2.25 | 9.00 | 4.50 |
| 12 | 60 | 2.25 | 13.50 | 18.00 | 11.25 | 15.75 | 11.25 | 4.50 | 13.50 | 11.25 | 4.50 |
| 18 | 60 | | 13.50 | 13.50 | 13.50 | 9.00 | 9.00 | 13.50 | 6.75 | 6.75 | 4.50 |
| 41 | 60 | | 13.50 | 13.50 | 15.75 | 11.25 | 9.00 | 15.75 | | 6.75 | 4.50 |
| 43 | 60 | 2.25 | 11.25 | 9.00 | 13.50 | 11.25 | 9.00 | 13.50 | 2.25 | 6.75 | 4.50 |
| 30 | 75 | 9.00 | 15.75 | 20.25 | 9.00 | 18.00 | 9.00 | 9.00 | | 6.75 | 4.50 |
| 31 | 75 | | 4.50 | 11.25 | 9.00 | 9.00 | 6.75 | 2.25 | 2.25 | 6.75 | 4.50 |
| 33 | 75 | 9.00 | 9.00 | 24.75 | 15.75 | 11.25 | 11.25 | 6.75 | | 6.75 | 4.50 |
| Totals . . . | | 24.75 | 103.50 | 157.50 | 128.25 | 139.50 | 85.50 | 49.00 | 27.00 | 85.50 | 49.50 |

TABLE 4.—*Number of flowers opening weekly on individual cotton plants grown in potometers in 1916, with the number on 10 plants in the field.*

| Plant number. | Week ending | | | | | | |
|---|---|---|---|---|---|---|---|
| | July 25. | Aug. 8. | Aug. 14. | Aug. 22. | Aug. 28. | Sept. 4. | Sept. 12. |
| 4 | | 1 | 4 | 10 | 8 | 5 | 5 |
| 11 | | | | 4 | 9 | 11 | 16 |
| 17 | | | 3 | 8 | 9 | 5 | 4 |
| 36 | | 3 | 5 | 10 | 8 | 9 | 1 |
| 12 | | 3 | 8 | 15 | 14 | 9 | |
| 18 | | | 1 | 8 | 11 | 7 | 4 |
| 41 | | 2 | 4 | 10 | 7 | 7 | 6 |
| 43 | | 2 | 4 | 8 | 8 | 9 | 2 |
| 30 | | 7 | 5 | 12 | 6 | 3 | |
| 31 | | | 2 | 5 | 2 | 9 | 6 |
| 33 | | 15 | 8 | 16 | 3 | | |
| Total on 11 plants....... | | 33 | 44 | 105 | 85 | 74 | 42 |
| Total on 10 field plants... | 53 | 44 | 85 | 146 | 58 | 37 | 8 |

The water record in 1916 was carried a little later than in 1915, and showed a considerable demand by the plant well into the fall months. The greatest amount of water was applied to the plants during the four weeks of August, the highest week being the second. On account of the heavy rainfall on July 15 the field plants did not

bloom earlier than the plants in the cans; the maximum blooming period for both was during the third week in August. Except for No. 11 which was accidentally topped, the plants in the cans were quite regular in their period of blooming.

Most farmers are not satisfied if they have not laid their cotton by so that they are free to go fishing by July 4. If the results here presented are of any value, they indicate that later cultivation than is usually given would be of benefit in conserving soil moisture for the use of the plants during the hot summer weather.

# AGRONOMIC AFFAIRS.

## OFFICIAL CHANGES.

Because of a change in his official duties and his removal from Washington incident thereto, Mr. P. V. Cardon has resigned as Secretary-Treasurer of the Society, effective March 15. Mr. Lyman Carrier, of the Office of Forage-Crop Investigations, U. S. Department of Agriculture, and a former Treasurer of the Society, has been appointed acting Secretary-Treasurer by President Lyon, and all correspondence regarding memberships and dues should be addressed to him at Washington.

Attention is also called to the changes in the standing committees of the Society, as shown on the back cover page of this number. On the Committee on Soil Classification and Mapping J. G. Mosier and C. A. Mooers have succeeded G. N. Coffey and L. J. Briggs. President Lyon has removed himself as chairman of the Committee on Standardization of Field Experiments and has appointed A. T. Wiancko, a former member of the committee, in his stead; new members on this committee are F. S. Harris and S. C. Salmon, the latter succeeding W. M. Jardine. No changes were made in the Committee on Terminology. On the Committee on Varietal Nomenclature, W. C. Etheridge has succeeded C. G. Williams. The whole-hearted cooperation of the entire membership with these new officers and committeemen is earnestly solicited.

## ANNUAL DUES FOR 1918.

Under the by-laws of the Society, the JOURNAL is not to be sent to those who have not paid their dues by April 1. Because of a change in the Secretary-Treasurership and other conditions which have some-

what delayed collections this year, the April number is being sent to all members whose dues for 1917 are paid, as well as all new members for 1918. Before the May number is mailed, however, the payment of dues will be checked and those who are in arrears for 1918 will be taken off the mailing list. If you have not already paid your dues for 1918 and wish to continue to receive the JOURNAL promptly you should remit the amount, $2.50, promptly to the new Secretary-Treasurer, Mr. Lyman Carrier, U. S. Department of Agriculture, Washington, D. C.

## MEMBERSHIP CHANGES.

The membership reported in the March issue was 638. Since that time 9 new members have been added, 2 have been reinstated, and 1 has resigned, a net gain of 10 members and a present membership of 648. The names and addresses of the new members and of the two reinstated, the name of the one resigned, and such changes of address as have been noted since the last issue, are as follows:

### NEW MEMBERS.

CLEVENGER, C. B., College of Agriculture, Madison, Wis.
GILLIS, M. C., 401 E. Douglas St., Bloomington, Ill.
IBERICO, JUAN R., Yurimaguas, Loreto, Peru, S. A., via Para, Brazil.
LOVE, RUSSELL M., R. F. D. No. 2, Tarentum, Pa.
RUNK, C. R., 250 W. Tenth Ave., Columbus, Ohio.
SMITH, V. C., College of Agriculture, Columbus, Ohio.
VEACH, C. L., College of Agriculture, Athens, Ga.
WATER, E. J., 91 West 11th St., Columbus, Ohio.
YOUNG, PHILIP H., Kans. State Agr. College, Manhattan, Kans.

### MEMBERS REINSTATED.

McCALL, M. A., Lind, Wash.
NEWTON, ROBT., E Battery, Can. Anti-Aircraft B.E.F., France, via P. M., New York, N. Y.

### MEMBER RESIGNED.

SUDDATH, ROBERT O.

### CHANGES OF ADDRESS.

BINFORD, E. E., Dadeville, Ala.
BLEDSOE, R. PAGE, Experiment Station, Waterville, Wash.
BRYANT, RAY, Stillwater, Okla.
BURSCH, DAN M., R. F. D. No. 3, Chanute, Kans.
BUSHEY, A. L., Plankinton, S. D.
CARROLL, J. S., Starkville, Miss.
CHAPMAN, JAMES E., 1812 Linden Ave., Baltimore, Md.

DEATRICK, EUGENE, Mont Alto, Pa.
DOUGLAS, J. P., 402 E. Chalmers St., Champaign, Ill.
KEMP, ARNOLD M., Fairmount, Ind.
KENNARD, F. L., Colfax, Wash.
LECHNER, H. J., Court House, Astoria, Ore.
MORRISON, J. D., Elbon, S. Dak.
NASH, C. W., Morris, Minn.
THOMAS, MELVIN, Charleston, Ill.
WALLER, ALLEN G., 2028 F St., NW., Washington, D. C.
WALSTER, H. L., 5520 Blackstone Ave., Chicago, Ill.

Mail for the following members has been returned unclaimed. Any one knowing the present address of any of these members will confer a favor on the Secretary-Treasurer by reporting the information to him.

BLISS, S. W.,
BOARDMAN, W. C.,
FREEMAN, RAY,
HURST, J. B.

## ROLL OF HONOR.

In the February JOURNAL a list of those members of the Society who were known to be serving their country in its military forces was published. Since that time, a number of names have been added to the list. The editor will appreciate the favor if those who know of other members of the Society than those noted below who should be added to this list will send their names to him.

SAMUEL D. GRAY,
E. E. GRAHAM,
M. B. GILBERT,
A. D. ELLISON,
JAMES E. CHAPMAN,
H. R. CATES,
A. M. BRUNSON,
B. B. HOLLAND,
O. F. JENSEN,
C. H. KARLSTAD,
P. H. KIME,
LEROY MOOMAW,
J. A. PURINGTON,
J. V. QUIGLEY,
GEO. T. RATLIFFE,
L. C. RAYMOND,
PHIL. E. RICHARDS,
F. J. SCHNEIDERHAN,
W. R. SCHOONOVER,
HERSCHEL SCOTT,
PAUL TABOR.

## NOTES AND NEWS.

G. M. Garren is now assistant agronomist in plant breeding at the North Carolina station.

E. J. Holben has been appointed assistant in experimental agronomy at the Pennsylvania station.

R. R. Hudelson, assistant professor of soils in the University of Missouri, is now a first lieutenant of artillery and E. M. McDonald, assistant professor of farm crops in the same institution, is a second lieutenant of infantry in the National Army.

W. M. Jardine, president of the American Society of Agronomy in 1917 and for the past several years dean and director of the Kansas college and station, has been elected president of that institution, succeeding H. J. Waters, who, as previously noted, is now managing editor of the *Kansas City Weekly Star.*

H. G. Knight, for the past several years dean and director of the Wyoming college and station, has been elected to a similar position in Oklahoma and assumed his new duties February 1. He was succeeded in Wyoming by A. D. Faville.

F. G. Merkle, who has been assistant in the department of agronomy in the Massachusetts Agricultural College during the past year, has been made an instructor in the same department.

M. F. Miller, professor of soils in the University of Missouri, has been made assistant dean of the college and assistant director of the station in addition to his other duties.

J. A. Purington, of the Massachusetts college, enlisted in the U. S. army last December. He was on the *Tuscania* when she was sunk by a submarine in February, but was fortunate enough to be numbered among the survivors and at last reports was somewhere in England.

H. N. Vinall has been at Wichita, Kans., for the past two months, supervising purchases of grain sorghum and other seeds for sale to farmers at cost in the drought-stricken regions of Oklahoma and Texas where there was a general failure last year. This work is being done for the Seed Stocks Committee of the U. S. Department of Agriculture.

## Meeting of the Ohio Section.

The Columbus (Ohio) Section of the American Society of Agronomy held its second annual meeting on Wednesday afternoon, January 30, 1918, in Townsend Hall, Ohio State University. At this meeting Mr. J. W. Ames, chief chemist of the Ohio Agricultural Experiment Station, discussed "Sulfofication in Relation to Nitrogen Transportation in Soils." Dr. J. F. Lyman, Department of Agricultural Chemistry and Soils of the Ohio State University, discussed "The Food Problem and the War." About 30 men were in attendance at the meeting, and took part in the discussion of these two subjects. The meeting was very profitable and enjoyable. The officers elected for the coming year were: President, Firman E. Bear; and Secretary-Treasurer, Wallace E. Hanger.

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# THE EFFECT OF SODIUM NITRATE APPLIED AT DIFFERENT STAGES OF GROWTH ON YIELD, COMPOSITION, AND QUALITY OF WHEAT—2.[1]

J. DAVIDSON AND J. A. LE CLERC.

## INTRODUCTION.

In a previous paper[2] were reported the effects of sodium nitrate applied at different stages of growth on the yield of crop, percentage of yellowberry, and protein content of the grain. It was shown that when applied at the first stage, sodium nitrate increased very considerably the yield of the crop, that when applied at the second stage it increased the protein content and "flintiness" of the grain, and that when applied at the third stage it did not have any effect either on the yield of the crop or on the composition and quality of the grain. Attention was called to the new method of plotting used in the experiment. The plots were laid out after the crop was up, each plot showing uniformity of plant growth. This made it possible to limit the size of the plot to one square rod with very satisfactory results. It may be stated in passing that experiments carried out this year in Nebraska fully corroborate our observations made in our experiments conducted last year in Kentucky with reference to the particular effect of nitrogen at the different stages of growth and with

[1] Contribution from the Plant Chemical Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Davidson, J., and Le Clerc, J. A. The effect of sodium nitrate applied at different stages of growth on the yield, composition and quality of wheat. *In* Jour. Amer. Soc. Agron., 9: 145–154. 1917.

reference to adaptability of our new method of plotting for experiments of this kind.

In this paper we want to present and discuss some additional data obtained in our last year's experiments, namely, the effect on the ash, potash, and phosphoric acid content of the grain, and on the nitrogen content of the straw.

## Ash, Phosphoric Acid and Potash.

As seen from Table 1, the various treatments in the experiment did not affect the ash, phosphoric acid, or the potash content of the grain in any distinct or concordant manner. The variations in the phosphoric acid are on the whole very slight. Should these small varia-

Table 1.—*Percentage of ash, phosphoric acid, and potash in the grain from plots to which nitrate of soda was applied in various quantities at various stages of growth.*

| Fertilizer added at each application. | No. of applications. | Stages of growth. | Percentage of ash. Water applied. Fertilizer in solution. | Percentage of ash. Water applied. Fertilizer in solid state. | Percentage of ash. No water applied. | Percentage of $P_2O_5$. Water applied. Fertilizer in solution. | Percentage of $P_2O_5$. Water applied. Fertilizer in solid state. | Percentage of $P_2O_5$. No water applied. | Percentage of $K_2O$. Water applied. Fertilizer in solution. | Percentage of $K_2O$. Water applied. Fertilizer in solid state. | Percentage of $K_2O$. No water applied. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 lbs. $NaNO_3$........ | 1 | First | 1.90 | 1.98 | 2.05 | 1.02 | .99 | 1.00 | .542 | .524 | .538 |
| | | | 1.82 | 1.86 | 1.97 | .93 | .92 | .96 | .527 | .522 | .533 |
| Do. ........ | 1 | Second | 1.95 | 1.95 | 1.98 | 1.03 | 1.03 | 1.04 | .551 | .559 | .552 |
| | | | 1.90 | 1.92 | 1.99 | .99 | .98 | 1.00 | .495 | .495 | .550 |
| Do. ........ | 1 | Third | 1.86 | 1.89 | 1.98 | .99 | 1.03 | 1.01 | .539 | .555 | .540 |
| | | | 1.94 | 1.88 | 2.04 | 1.00 | 1.00 | 1.03 | .533 | .528 | .542 |
| 1 lb. $NaNO_3$......... | 2 | First and second | 1.9[illegible] | 1.95 | 1.82 | 1.00 | 1.01 | .94 | .552 | .555 | .502 |
| | | | 1.88 | 1.75 | 1.88 | .95 | .92 | .95 | .507 | .490 | .527 |
| Do. ........ | 2 | Second and third | 1.97 | 2.01 | 2.17 | 1.03 | 1.01 | 1.05 | .548 | .560 | .529 |
| | | | 1.91 | 1.99 | 2.08 | .97 | .95 | 1.04 | .487 | .483 | .545 |
| Do. ........ | 2 | First and third | 1.88 | 1.85 | 1.95 | .98 | 1.00 | .95 | .544 | .526 | .543 |
| | | | 1.97 | 1.82 | 1.83 | .97 | .90 | .91 | .508 | .478 | .493 |
| ⅔ lb. $NaNO_3$........ | 3 | First, second and third | 2.09 | 1.91 | 1.92 | 1.02 | 1.02 | 1.01 | .521 | .555 | .525 |
| | | | 1.80 | 1.92 | 1.80 | .94 | .96 | .93 | .503 | .504 | .498 |
| 2 lbs. $NaNO_3$ + 2 lbs. KCl | 1 | First | 1.57 | | 1.73 | .90 | | .86 | .507 | | .486 |
| | | | 1.91 | | 1.84 | .95 | | 1.02 | .533 | | .526 |
| Do. | 1 | Second | 1.78 | | 1.83 | .98 | | .97 | .526 | | .505 |
| | | | 1.98 | | 1.87 | 1.01 | | .98 | .504 | | .500 |
| Do. | 1 | Third | 1.77 | | 2.02 | .97 | | .97 | .544 | | .510 |
| | | | 1.93 | | 1.92 | .96 | | 1.03 | .518 | | .543 |
| 2 lbs. KCl............ | 1 | First | 1.86 | | 2.06 | 1.00 | | 1.01 | .541 | | .555 |
| | | | 1.95 | | 1.89 | 1.03 | | .97 | .536 | | .558 |
| Do. ........... | 1 | Second | 1.78 | | 1.93 | .97 | | .98 | .534 | | .528 |
| | | | 1.91 | | 2.07 | .99 | | .97 | .509 | | .502 |
| Do. ........... | 1 | Third | 1.94 | | 1.84 | .98 | | .95 | .549 | | .513 |
| | | | 1.97 | | 1.89 | 1.00 | | 1.00 | .544 | | .539 |
| Check.... ......... | | | 2.04 | | 1.99 | 1.06 | | .98 | .576 | | .582 |
| | | | 2.02 | | 1.89 | .99 | | 1.04 | .524 | | .529 |

tions be taken into consideration there is possibly a very slight tendency toward a somewhat higher phosphoric acid content in those cases where the nitrogen was applied in the second stage. It would be useless, however, to speculate whether the nitrogen applied at the first stage caused a depression in the phosphoric acid or whether the nitrogen applied at the second stage stimulated the phosphoric assimilation. Headden[3] found a distinct depression in the phosphoric acid content when sodium nitrate was applied. More experimentation is necessary in order to decide whether the results obtained by Headden are the rule, our results being the exception, or vice versa. It is likely that Headden's results are the rule, as there are certain theoretical considerations which would be in harmony with this substitution of nitrogen for phosphorus. The case would be similar to the substitution of sodium for potassium. We will perhaps be able to throw some light on the question when we are ready to report on the results of our Nebraska experiments. With reference to the ash and the potash content there is no tendency toward any consistency whatever.

### Protein Content in Straw.

The term protein with reference to straw represents the total nitrogen multiplied by 6.25. The protein content is given instead of the nitrogen content, both for the sake of uniformity and to accentuate the consistent variations in the nitrogen content. As seen from Table 2 the protein content in the straw follows the same tendency as the protein content in the grain. The straw of the plots which received the sodium nitrate at the second stage shows a distinctly increased protein content, the increase being proportional to the amount received. Of the plots which received their nitrogen in two stages those which received it in the first and second stage, and in the second and the third respectively show an appreciable increase of protein in the straw; those, however, which received it in the first and the third stage do not show such an increase. The same is true about the plots which received the full application in the first and third stages respectively.

The application of potassium chloride depressed very distinctly the protein content of the straw. This observation is in full accordance with the results of Headden, who found that potassium chloride depressed the nitrogen in the plant but not in the grain.[4] From Table

[3] Headden, W. P. A study of Colorado wheat. Colo. Agr. Expt. Sta. Bul. 219.

[4] Loc. cit.

2 it will also be noted that the yield of straw was increased whenever nitrates were added at the first sage. The application of KCl had no effect on the yield, irrespective at what stage the potash salt was applied.

TABLE 2.—*Percentage of protein in straw and weight of straw from plots to which nitrate of soda was applied in various quantities at various stages of growth.*

| Fertilizer added at each application. | No applications. | Stages of growth. | Percentage of protein in straw. | | | Weight of straw, lbs. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Water applied. | | No water applied. | Water applied. | | No water applied. |
| | | | Fertilizer in solution. | Fertilizer in solid state. | | Fertilizer in solution. | Fertilizer in solid state. | |
| 2 lbs. $NaNO_3$ ......... | 1 | First | 4.12<br>4.74 | 4.47<br>4.39 | 4.65<br>4.91 | 22.1<br>20.2 | 22.8<br>17.8 | 20.4<br>19.7 |
| Do. ......... | 1 | Second | 6.69<br>6.50 | 6.05<br>5.74 | 6.50<br>6.62 | 9.5<br>9.4 | 10.8<br>9.4 | 9.8<br>7.4 |
| Do. ......... | 1 | Third | 4.55<br>4.12 | 4.65<br>4.43 | 4 30<br>3.91 | 10.3<br>8.4 | 9.5<br>9.1 | 9.8<br>9.1 |
| 1 lb. $NaNO_3$.......... | 2 | First and second | 5.17<br>4.52 | 5.61<br>4.78 | 5.44<br>4.91 | 16.3<br>17.5 | 15.9<br>15.7 | 16.3<br>16.8 |
| Do .......... | 2 | Second and third | 5.41<br>5.83 | 5.00<br>5.44 | 6.25<br>5.48 | 11.0<br>7.4 | 9.3<br>8.6 | 9.3<br>8.2 |
| Do. .......... | 2 | First and third | 3.95<br>3.77 | 4.47<br>4.25 | 4.74<br>4.68 | 17.1<br>16.1 | 15.5<br>15.7 | 15.7<br>15.9 |
| ⅔ lb. $NaNO_3$ ........ | 3 | First, second and third | 4.65<br>4.82 | 5.09<br>4.52 | 5.17<br>4.47 | 12.7<br>13.4 | 12.6<br>13.9 | 14.9<br>16.4 |
| 2 lbs. $NaNO_3$ + 2 lbs. KCl | 1 | First | 4.65<br>3.95 | | 3 77<br>4.47 | 20.0<br>24.6 | | 19.4<br>21.8 |
| Do. | 1 | Second | 6.37<br>5.96 | | 5.44<br>5.92 | 9.0<br>12.0 | | 9.1<br>10.6 |
| Do. | 1 | Third | 4.21<br>4.17 | | 3.68<br>3.86 | 9.3<br>11.2 | | 7.8<br>9.5 |
| 2 lbs. KCl............. | 1 | First | 3.24<br>3 69 | | 3.24<br>3.99 | 8.8<br>10.8 | | 11.1<br>9.2 |
| Do. .. ........... | 1 | Second | 3.50<br>3.82 | | 3.77<br>3.64 | 10.5<br>11.6 | | 10.2<br>9.6 |
| Do. .. ........... | 1 | Third | 3.42<br>3.64 | | 3.32<br>3.59 | 9.1<br>9.9 | | 8.4<br>10.0 |
| Check ............... | | | 3.95<br>3.86 | | 4.04<br>4.21 | 12.4<br>9 1 | | 8.5<br>10.9 |

These results bear out further our conclusion that within the limits of our experiment it is the presence of nitrogen in the soil at the second stage which is responsible for the increase of the protein content in the grain and straw and for prevention of yellowberry in the grain. Headden's[5] work can be interpreted to agree with the results obtained in our experiment. Headden applied his nitrogen at a

[5] Headden, W. P. Yellow berry in wheat, its cause and prevention. Colo. Agr. Expt. Sta. Bul. 205.

period which corresponded to our first stage and obtained a flinty grain high in protein. But the crop in his experiments did not respond in yield to the application of the nitrate, as nitrogen is not the limiting factor in the soils of Fort Collins. The added nitrate was not used up by the plant during the first stage of growth. The local condition further excludes the possibility of the removal of the nitrates by drainage. The added sodium nitrate consequently was present in the soil at the time which corresponds to our second stage of growth. It is the presence of the nitrate at this stage which, in our opinion, prevented yellowberry and produced a high protein content in the experiments of Headden.

Headden[6] comes further to the conclusion, on the basis of his experiments, that flintiness and high protein content are a function of the soil and not of climate. According to the conclusion of Le Clerc and his associates[7] as a result of three years' experiments, climate and not soil played the predominant part in influencing the composition and flintiness of wheat. In reality, however, the results obtained by Headden are not necessarily at variance with the conclusions reached in the Laboratory of Plant Chemistry. Under ordinary field conditions the crops depend for their nitrogen upon nitrification which is favored or hindered to a very considerable extent by climatic conditions. If Headden obtained the same results in a year which was very unfavorable with reference to rainfall as were obtained in a normal year it was probably because in his experiments the crop did not depend upon nitrates produced in the soil during that year, as he added ready-made sodium nitrate.

## Summary.

1. No conclusion can be drawn from our experiments with reference to the effect of sodium nitrate on the ash, phosphoric acid, and potash content of the grain.

2. The protein content in the straw showed the same tendencies as the protein content in the grain, i. e., there was an increased protein content as a result of the nitrate applied at the second stage.

3. An increase in the yield of straw as well as of grain was noted whenever nitrates were applied at the first stage.

[6] Headden, W. P. A study of Colorado wheat. Colo. Agr. Expt. Sta. Bul. 219.

[7] Le Clerc, J. A., and Leavitt, S. Trilocal experiments on the influence of environment on the composition of wheat. U. S. Dept. Agr., Bur. Chem. Bul. 128.

Le Clerc, J. A., and Yoder, P. A. Environmental influences on the physical and chemical characteristics of wheat. *In* Jour. Agr. Research, 1: 275. 1914.

4. Potassium chloride depressed the protein content in the straw.
5. Headden's work can be interpreted to agree with the results of our experiments.
6. The results of Headden's experiments as well as our own are not opposed to the conclusion of Le Clerc and his associates that flintiness and high protein content are a function of climate.

*Erratum*.—In the first paper by these authors, published in Jour. Amer. Soc. Agron., vol. 9, no. 4, on p. 150, Table 1, read "Yield of crop (grain and straw), pounds." instead of "Yield of grain, pounds."

# THE DETERMINATION OF MOISTURE IN SOILS.[1]

B. S. Davisson and G. K. Sivaslian.

## Introduction.

The method commonly employed for determining moisture in soils is that of direct drying in an air oven heated by various means, as steam, gas, or electricity. A desire to overcome the objectionable features of these methods and to obtain an absolutely dry basis instigated the work reported in this paper. The objections which should be overcome are the long time necessary for removing the moisture, the contamination of the sample by gases from combustion, the oxidation of the organic material due to the long heating at a temperature of 105° to 110° C. in air ovens, and the incomplete removal of all the moisture from the sample.

## Historical.

In 1898 Tryller[2] constructed a drying oven in which the heat from the small ring burners passed through a series of spaces in the walls and out at the top. The idea of this construction is to prevent contact between the soils and gases resulting from combustion. The author considered the results obtained by this oven to be sufficiently concordant for accurate work. However, drying for fourteen days at 105° C. and cooling and weighing daily did not yield absolute nor constant results. Often the sample shows an increase in weight after

[1] Contribution from the Laboratory of Soil Technology, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication February 23, 1918.

[2] Tryller, ——. Über die Bestimmung der Trokensubstanz im Torf. *In* Landw. Versuchs., 49: 145. 1898.

it has decreased considerably. The author maintains that drying with his oven is essentially as satisfactory as drying in a vacuum desiccator.

Puchner[3] discusses Tryller's drying oven and admits that it prevents, to a certain extent, the action of gaseous products of combustion. He holds that the irregularity of the results obtained by Tryller are due to the unequal heating of different parts of the oven and the condensation of mositure on the glass and the soil, due to the high hygroscopicity, while transferring the sample to the desiccator. He then carried out some experiments in which he covered the dishes in the oven and left them covered when cooling in the desiccator. Better results were obtained in this way but they were not absolute. Puchner concludes that drying of a soil at 105° C. in such an oven does not give the actual moisture content and that soil analysis based upon such moisture determinations cannot be entirely correct.

Mitscherlich[4] gave some time to accurate moisture determinations in soils and finally recommended drying in a vacuum over phosphorus pentoxide at 100° C. He used individual vacuum desiccators with phosphorus pentoxide for each sample. The desiccator after evacuation was placed in an air oven at the desired temperature. Because of the thickness of the walls of the desiccator it was found that the temperature of 100° C. within the desiccator could be more easily obtained by suspending the vessel in an oven and allowing live steam to come in contact with the walls of the desiccator. Mitscherlich employed wheat starch for studying the drying process because it remained unchanged during the drying. He found that increasing the temperature lessened greatly the time necessary for drying the sample. Four hours' drying was found sufficient to remove all the moisture from the starch or soil sample at 100° C., thus showing that the method gives absolute dryness, the dry substance remaining constant during five to nine hours' further drying. The author calls attention to the error introduced by handling the drying dishes with the bare hands.

König[5] used an electrically heated vacuum desiccator in which he maintained a temperature of 100° C. and used phosphorus pentoxide as the desiccant. The weighings were repeated to constant weight. A comparison of the results obtained by this method and by direct

[3] Puchner, H. The determination of dry matter in soil samples. *In* Landw. Versuchs., 55: 309. 1901.

[4] Mitscherlich, A. Zur Methodik der Bestimmung der Benutzungswarme des Akerbodens. *In* Landw. Jahrb. 31: 578. 1902.

[5] König, J. Relations between the properties of soils and the assimilation of foods by plants. *In* Landw. Versuchs., 66: 415. 1907.

drying at 105° to 110° C. does not show any very marked difference in the amount of moisture obtained upon different soil samples.

Although considerable attention has been given to the subject of moisture determinations in soils, the positive evidence of the superiority of any method is not conclusively established. It must be admitted that direct drying in an air oven does not give absolutely trustworthy results. The drying in a vacuum over phosphorus pentoxide at 100° C. appears to be superior to drying in an air oven. The time necessary for a moisture determination is greatly lessened by the vacuum method.

A comparison of the methods reported seemed necessary to establish fully the method which gives the most reliable results. A comparison of direct drying in gas and electrically heated ovens and in a vacuum over phosphorus pentoxide at 105° C. constitutes the experimental part of this paper.

## Experimental.

The gas oven used in this work is the ordinary copper oven provided with a jacket for a liquid bath. Oil was used in this oven and by careful manipulation the temperature was maintained very constant at 105° C. No precaution was taken to prevent the gas fumes from coming in contact with the samples as they were being dried. The oven was used as it is generally in laboratories for drying. The electrically heated oven is one of the common types on the market having a control thermostat. The temperature was kept constant at 105° C. at the shelf on which the samples were placed.

In the first work of drying in a vacuum at 105° C. over phosphorus pentoxide, desiccators were used, but it was found practically impossible to maintain a vacuum in other than a glass desiccator and the glass desiccators which were obtainable would not withstand the temperature. An electrically heated vacuum oven was obtained and was found to be very satisfactory. Trouble was experienced in getting a tight seal between the door and the chamber without the use of some kind of sealing material. For this purpose a mixture was prepared by mixing finely divided graphite and melted beeswax until the mixture became very thick and pasty. After cooling, this material was cut into pencils. A pencil was then drawn around the face of the warm door until a good coating of the contact face was obtained. Upon closing the door this graphite sealed it very tightly and a vacuum could be easily maintained for twenty hours. All dryings were made at 105° C. and about 1.5 cm. pressure. At the end of the drying

period the vacuum was broken slowly and the ingoing air thoroughly scrubbed through concentrated sulfuric acid. The phosphorus pentoxide was placed in a shallow dish on a shelf about 3 inches below the shelf on which the samples were placed.

The samples, 10 grams, were weighed into glass weighing dishes 5 cm. in diameter and 3 cm. deep with ground-glass covers. Larger dishes, 7½ cm. × 3 cm. were compared with the smaller ones and found to be no better for a 10-gram sample. After drying, the dishes were closed and cooled in desiccators over calcium chloride and were weighed. It was found to be bad practice to place many samples in one desiccator because the opening of the desiccator to remove dishes permitted moisture to enter and those dishes remaining longest in the desiccator gave lower values for moisture. It is advisable to use an individual desiccator for each sample when accurate work is desired. In no case should the bare hands be allowed to touch the dishes after being cleansed for the sample.

Cornstarch was used for checking the methods because of its finely divided condition, high hygroscopicity, homogeneity, and its remaining unchanged during the drying process. The employment of such a substance makes it easy to establish if an absolutely dry substance can be obtained. The starch was uniformly mixed and preserved in glass-stoppered bottles.

The data obtained for the moisture content of the starch sample by the vacuum method are reported in Table 1. The total moisture was removed in a period of two hours, when further drying did not yield any change in the moisture content.

TABLE 1.—*Grams of moisture in 10 grams of starch, as shown by drying for different periods in a vacuum oven over $P_2O_5$ at 105° C.*

| Time of drying, hours. | Number of determination. | | | | | Average. |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| One | 1.2711 | 1.2638 | 1.2650 | 1.2361 | 1.2603 | 1.2592 |
| Two | 1.2897 | 1.2938 | 1.2950 | 1.2960 | 1.2950 | 1.2939 |
| Three | 1.2953 | 1.2962 | 1.2954 | 1.2902 | 1.2889 | 1.2932 |
| Four | 1.2948 | 1.2914 | 1.2936 | 1.2960 | 1.2915 | 1.2934 |

Ten determinations were then made to obtain the probable error of the method. The error calculated by the method of least squares is satisfactorily low and shows that very consistent results can be obtained. The determinations of moisture in grams in 10-gram samples of starch were as follows: 1.2963, 1.2947, 1.2942, 1.2953, 1.2941, 1.2926, 1.2927, 1.2936, 1.2888, and 1.2976, with an average of

1.2939 and a probable error of ±0.0017, or a percentage error of ±0.001.

A starch sample was then subjected to drying at the same temperature but no phosphorus pentoxide was used to absorb the moisture. The vacuum pump was kept running all the time. On drying for two hours with this method a new sample of starch gave 1.2804 grams of moisture. The same starch yielded 1.2203 grams of moisture in two hours and 1.2739 grams in 24.5 hours when no phosphorus pentoxide was used. This shows that the moisture can not be removed easily without the use of the pentoxide and the time necessary for drying the sample is lessened greatly when the oxide is used.

Drying in electric and gas ovens was then compared with the vacuum method. The data in Table 2 show the superiority of the vacuum method. The moisture obtained by direct drying is far

TABLE 2.—*Grams of moisture in 10 grams of starch as shown by drying in ovens of various kinds at a uniform temperature of 105° C.*

| Kind of oven. | Time of drying, hours. | Number of determination. | | | | | Average. |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| Vacuum, over $P_2O_5$..... | 2.00 | 1.2817 | 1.2766 | 1.2792 | 1.2816 | 1.2829 | 1.2804 |
| Electric.............. | 16.50 | 1.2581 | 1.2534 | 1.2429 | 1.2556 | 1.2323 | 1.2484 |
| Gas .................. | 26.25 | 1.2213 | 1.2159 | 1.2210 | 1.2195 | 1.2202 | 1.2195 |

below that obtained by the vacuum method. The electric oven gave higher results than the gas oven and the results within themselves are not as concordant as those of the vacuum method. The superiority of the electric oven over the gas oven is shown and for this reason the gas oven was not employed in studying the moisture determinations on soils.

The data obtained for comparison of the electric oven and the vacuum method as applied to soils are found in Table 3. Clay and muck soils were used for this study because they present greater difficulties of moisture determinations than other soils, due to their large amount of surface and high hygroscopicity. The soils were air dried and ground to pass a 20-mesh sieve. Ten-gram samples were used. The data show the superiority of this vacuum method. The electric oven gave results 2.2 percent less for muck and 3.4 percent less for clay than the total moisture found by the vacuum method. It is also shown that 4 hours' drying is sufficient to remove the moisture by the vacuum method, whereas the electric oven did not yield definite results in 10 hours' drying.

TABLE 3.—*Grams of moisture in 10-gram samples of muck and of clay soil, as determined by drying for different periods in a vacuum oven over $P_2O_5$ and in an electric oven.*

MUCK SOIL.

| Kind of oven. | Time of drying, hours. | Number of determination. | | | | | Average |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| Vacuum, over $P_2O_5$..... | 2.0 | 1.8762 | 1.8814 | 1.8892 | 1.8806 | 1.8792 | 1.8813 |
| Do. ..... | 4.0 | 1.9035 | 1.9125 | 1.9016 | 1.9032 | 1.8994 | 1.9040 |
| Do. ..... | 7.0 | 1.9055 | 1.9148 | 1.9088 | 1.9087 | 1.9022 | 1.9080 |
| Electric............... | 4.0 | 1.7764 | 1.8403 | 1.8491 | 1.8332 | 1.8296 | 1.8257 |
| Do. ............... | 7.0 | 1.8200 | 1.8563 | 1.8612 | 1.8612 | 1.8619 | 1.8538 |
| Do. ............... | 10.0 | 1.8210 | 1.8533 | 1.8739 | 1.8732 | 1.8856 | 1.8612 |

CLAY SOIL.

| Kind of oven. | Time of drying, hours. | 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|---|
| Vacuum, over $P_2O_5$..... | 3.0 | 0.4451 | 0.4451 | 0.4412 | 0.4422 | 0.4435 | 0.4434 |
| Do. ..... | 5.0 | .4471 | .4473 | .4443 | .4525 | .4445 | .4471 |
| Do. ..... | 7.5 | .4467 | .4473 | .4434 | .4477 | .4425 | .4455 |
| Electric............... | 5.0 | .4191 | .4135 | .4293 | .4227 | .4150 | .4199 |
| Do. ............... | 8.5 | .4211 | .4305 | .4341 | .4234 | .4270 | .4272 |
| Do. ............... | 11.0 | .4215 | .4355 | .4306 | .4309 | .4278 | .4292 |

The vacuum method produced a dry soil, a condition which can not be obtained by the electric oven on several hours' drying. The danger of oxidation of the organic matter is removed when the vacuum method is employed. The loss of any volatile matter from drying in the vacuum oven will probably not be any greater than the loss which will take place on long drying in the gas or electric oven.

The air-drying oven is not capable of removing all the hygroscopic moisture from a soil sample. Soils having a high hygroscopicity will, therefore, retain considerable moisture under the ordinary procedure of drying and the results obtained will not represent the actual moisture content of the sample.

In order to show that the electric drying oven does not remove all the moisture from a soil sample, a determination was made by taking samples of muck soil and drying for 3½ hours in the vacuum oven over $P_2O_5$ at 105° C. The dry substance found was 8.0750 and 8.0978 grams for the two samples. These samples were then placed uncovered in a desiccator over 10 percent sulfuric acid and the desiccator evacuated. After standing in this desiccator for 15 hours the samples were removed and dried in the electric oven at 105° C. for 7.5 hours and the dry substance found was 8.1800 and 8.1688 grams. The samples were again placed over 10 percent sulfuric acid in a vacuum and after 15 hours they were dried by the vacuum method for 3.5 hours at 105° C., when the dry substance found was

8.0795 and 8.0938 grams, respectively. The values obtained by the electric oven are considerably higher than those obtained by the first drying of the soil sample by the vacuum method. The oven is, therefore, not capable of removing all the hygroscopic moisture from the soil. The second drying by the vacuum method gave results which are very nearly the same as those obtained by the first drying. This method of drying gives results which are definite and represent the actual moisture content of the soil. Soils having high hygroscopicity offer no difficulty in moisture determinations by the vacuum method, while direct drying fails to remove all the hygroscopic moisture.

## Conclusions.

1. Drying of soil samples in gas or electrically heated ovens will not give the true moisture content of the soils.

2. Drying by the vacuum method yields trustworthy and concordant results.

3. Four hours' drying at 105° C. in a vacuum over phosphorus pentoxide is sufficient to remove the moisture from soils having high hygroscopicity.

# THE MECHANICAL FACTORS DETERMINING THE SHAPE OF THE WHEAT KERNEL.[1]

SARKIS BOSHNAKIAN.

The shape of the grain of wheat is affected by a number of spikelet characters, which are mainly: (1) The stiffness of the glumes, (2) the size and shape of the space in which the grain develops, (3) the number of grains in the spikelet and their position, (4) the density of the head, (5) the pressure caused by the growth of different parts of the head, and (6) the species which produces the kernel. Just as the interior surface of stone or hard-shelled fruits determines to a very large extent the shape of the enclosed seed, so the character and form of the surroundings of the developing grain of wheat determine the shape of the mature kernel.

An ideal wheat kernel whose free development has not been arrested by coming in contact with the surrounding parts of the spikelet should be symmetrical; that is, when the grain is divided by a plane dorsi-ventrally passing through the crease, the two halves should be alike with the dimensions reversed. Such a grain is shown at *A* in figure 27. The position in the spikelet of uniformly developed kernels is seen in figure 27 *E*. Symmetrical grains are very rarely found in nature.

The types of kernel most frequently found are those shown in *B* and *C* of figure 27; their relative positions on the spikelet are shown in *Fb* and *Fc* respectively. In these cases the plane does not divide the grain into symmetrical halves. Grain *B* dorsally viewed is flattened on the left side, while in the case of *C* the opposite side is flattened. This flattening occurs always on the side of the kernel which is nearer to the rachis, as shown in *F*. It is evident then that all grains which are flattened on the left side are produced by the florets on the left side of the spikelets, and those flattened on the right side are borne on the opposite side of the spikelet. This character, which is constant for all species, enables one to determine the side of the spikelet on which different kernels were produced.

[1] Received for publication November 6, 1917.

All species of wheat do not produce this type of flattening in the same degree. In *Triticum vulgare*, although easily noticed, it is not so pronounced. The writer's observations of the various forms show that they rank about as follows with respect to their degree of flattening:

1. *Triticum vulgare;*
2. *T. capitatum;*
3. *T. compactum;*
4. *T. polonicum;*
5. *T. turgidum;*
6. *Triticum durum;*
7. *T. spelta;*
8. *T. dicoccoides;*
9. *T. dicoccum;*
10. *T. monococcum.*

In durums the degree of flattening varies with different varieties.

The extent to which flattening takes place depends primarily upon the stiffness and shape of the outer glumes; the stiffer the glumes

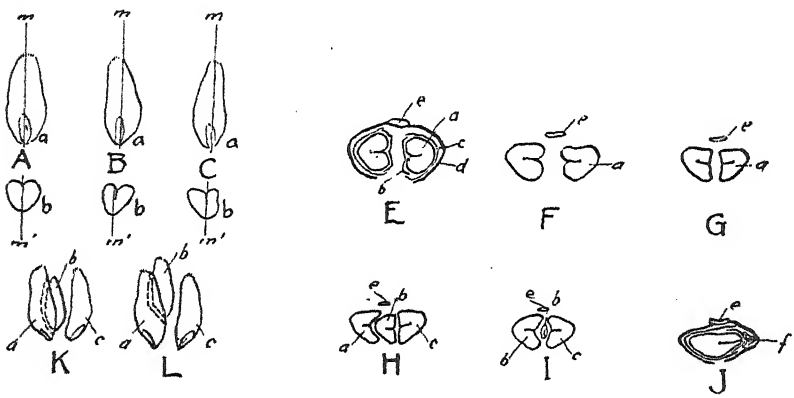


FIG. 27.—Types of wheat kernels. *Aa*, symmetrical grain; *Ab*, cross section (*m-m'*, axis). *Ba*, asymmetrical grain produced on left side of spikelet, left side of kernel flattened; *Bb*, cross section. *Ca*, asymmetrical grain borne on right side of spikelet, flattened on right side; *Cb*, cross section. *E*, cross section of spikelet showing position of well-developed symmetrical kernels; *a*, grain; *b*, palea; *c*, fertile glume; *d*, outer glume; *e*, rachis. *F*, position of grains with rounded cheeks, glumes not shown; note flattening of side of rachis, *e*. *G*, grains growing close together, showing flat cheeks. *H*, spikelet with the kernels tightly held together, showing effect of central spikelet *b* on the shape of the cheeks of the lateral kernels *a* and *c*; flattening of cheeks, as in *G*, taking place when grains *b* and *c* face ventrally, depression of crease taking place when the lateral kernel *a* faces the dorsal portion of the central kernel *b*. *I*, sterile or partially developed central floret producing slight depressions along the crease of the lateral florets *b* and *c*. *J*, spikelet of *T. monococcum* showing grain with protruded cheeks; *e*, rachis; *f*, sterile floret. *K* and *L*, effect of position of central grain *b* on the depression of crease of lateral grain *a*. *K*, depression on lower part of grain *a*. *L*, depression on upper portion of grain *a*.

the more tightly the grains are pressed toward the rachis. On the side of the rachis the grain does not have sufficient room for development and therefore does not fill up as fully on this side as it does on the other. The ranking shown above is in reality a ranking of the species according to the stiffness of their outer glumes.

The cheeks of the grain are the visible parts on each side of the crease when the kernel is viewed ventrally. The cheeks may be round and plump (*F*), flat (*G*), sunken with sharp edges (*I*), or protruded (*J*). The cheeks are filled, plump, and round (*E* and *F*) when the spikelet is soft and spreading, and contains not more than three grains. This type of a roomy spikelet will be found among the *vulgare* and squareheads, and in some of the clubs. The flattening of the cheeks (*G*) takes place when there are two kernels which face each other in the spikelet and when the latter is stiff and tends to press these two kernels together. The flattening of the cheeks in this case is mechanical.

The reader should be reminded that the grain of wheat throughout its period of development is very soft and that it hardens only after it attains its maximum development. Hardening is a drying process and occurs during the last few days of its period of maturation. As the kernel is very soft before this period, the slightest pressure on the grain through contact is very apt to modify its shape.

The process of the flattening of the cheeks of the wheat grain is not different from the flattening of the sides of the horse-chestnut. It will be remembered that when only one chestnut is developed from a flower it has more or less rounded sides; when, however, the flower produces two chestnuts the sides which face each other are flattened out instead of being rounded as in the first instance. We find the same phenomenon in maize. In well-fertilized ears the four sides of the kernels are flat, while in poorly fertilized ears where an isolated pair of kernels are found the sides of the grains which face are flat while the sides which do not come into contact remain rounded. This principle of flattening in this and in many other cases is due to pressure resulting through contact. Flat cheeks will be found as a rule among the 2-grained and tight-glumed species such as the wild wheat, the emmers, and most of the spelts.

When three grains are present (*I*) and the texture and form of the glumes are as in the previous case the cheeks of some of the kernels of the basal florets tend to sink or flatten, depending on the size and position of the seeds developing between the two basal grains. If the central grain is small (*Ib*), the cheeks of the large

kernels on both sides (*Ia* and *Ic*) of this tend to sink to fit the outline of the central grain (*Ib*). If on the other hand the middle grain is fairly large (*Hb*), usually the grains whose ventral sides face one another (*Hb* and *Hc*) are flattened ventrally more or less while the other outer grain (*Ha*), which faces the dorsal portion of the central kernel (*Hb*), develops a depression along the crease and the edges of the cheek become sharp. The presence of sterile florets in the center will produce a slight depression along the ventral surface.

The position of the central grain or grains will determine the region where the depression is to occur. If the small central grain (*Kb*) is located along the middle portion of the crease of the outer kernel (*Ka*) the depression occurs along that region. If it has a higher position (*Lb*) the upper portion of the cheek only will be depressed (*La*). Grains of this third type occur particularly among spelts and often in durums and English wheats.

The fourth and last case is that of the *monococcum*, whose spikelets almost always produce but one kernel. If the glumes were not stiff and did not press the grain inside tightly against the rachis the shape of the normally developed grain might approach that of the *vulgare*. On account of the pressure along the sides of the grain the latter naturally flattens, and since there is no other grain in the same spikelet which by contact will arrest the growth of the cheeks the latter keep on protruding until the grain attains its full size (*J*).

That considerable pressure is exerted by the glumes may be demonstrated by the presence of parallel vein marks on the sides of the grain of *monococcum*, especially that facing the rachis. The parallel sunken lines are the exact reproductions of the veins of the lemma that envelops the grain. The vein marks of the glumes could not have been impressed on the plastic grain without pressure and contact. Such vein impressions are also occasionally seen on the kernels of the spelts.

The shape of the kernel of the club wheats is often different from that of the others. The grains of this form are short and in some cases almost spheroid, depending of course upon the variety. The shortness of the grain is caused by the presence of a genetic factor or factors which shortens a number of size characters such as length of glumes, awns, internodes, culm, and kernel. This is not a physical factor.

In club wheats we find, besides shortness, an irregularity as regards the shape of the grain. Kernels obtained from the central portion of the head of most of the clubs are fairly symmetrical and

uniform, but those taken from the upper portion of the head, especially of squareheaded clubs, are irregular and often flattened somewhat like those of *Triticum monococcum*. This is due to the close and dense arrangement of the spikelets one above the other. When the internodes are short the spikelets spread out and arrange themselves almost at right angles with the rachis one above the other. Under such conditions the development of a kernel is checked through the growth of competing grains in spikelets above and below it. The pressure developed from growth acts along a direction perpendicular to the plane of symmetry of the kernel and tends to flatten out the cheeks. The irregularities are produced by pressure as well as by the crowding of the grain on the sides, above, and below each developing grain.

There are other mechanical causes affecting the shape of the grain; though mechanical they are not due to pressure. Irregularities on the surface of the grain are to a great extent the result of evaporation of the moisture in the grain. We have soft and hard grains with numerous intermediate gradations. Soft or starchy grains have almost always rounded cheeks; whereas those which are hard or corneous shrivel to some extent upon drying and consequently produce irregularities on the surface of the grain. This phenomenon is comparable with the smoothness of the surface of the soft starchy and the wrinkled surface of the sweet or dent corn.

The mechanical causes determining the shape of the grain should not be confused with the purely genetic factors which are to some extent responsible for the production of certain grain forms. Reference has already been made to the genetic causes affecting size of the kernels of dense wheats. The shortness of the grain of the club and the unusual length of that of the Polish wheat are not the results of any form of mechanical pressure but are already determined before the embryo begins to develop. The grain will remain short or grow long depending upon the species and the length factor which the plant carries.

There are many grain characters which are the result of both genetic and mechanical factors. It was said at the beginning of the discussion that the shape of the grain was primarily dependent upon the shape and stiffness of the glumes. The shape of the glumes varies with different species, and the grain whose shape is to a great extent dependent on that of the glumes varies also depending upon the species. The first cause in this case is genetic, but its result on the grain is mechanical. Most of the forms considered in this paper belong to the latter category.

# LOSS OF ORGANIC MATTER IN CLOVER RETURNED TO THE SOIL.[1]

George E. Boltz.[2]

## Introduction.

The practice of applying organic matter is generally considered more or less essential in maintaining and increasing the fertility of certain soils. The value of such soil treatment is supposed to be derived largely from the beneficial effects of the organic matter as well as the fertilizing elements incidentally carried by it. In many instances the fertilizing elements are considered only of secondary importance, while it is assumed that the organic matter in crops and manures is the chief factor which causes the increased productiveness of soils.

It is often advocated in agricultural literature that the most efficient method of maintaining or increasing the supply of organic matter in the soil is by the use of green manures and crop residues. This method is given preference over that of feeding the crop and returning the manure to the soil, because a large percentage of the organic matter is destroyed in passing through the animal. With clover this loss represents about 66 percent of the total organic matter present in the crop. By incorporating the green crop directly in the soil or by cutting and allowing it to remain on the surface for some time before plowing under, it is assumed that this loss is greatly reduced if not entirely avoided.

In order to obtain information regarding the loss of organic matter from a clover crop used for green manuring as compared with the loss when fed to farm animals and returned to the soil in the form of manure, experiments were conducted at the Ohio Agricultural Experiment Station with the results here given.

[1] Contribution from the Ohio Agricultural Experiment Station, Wooster, Ohio. Publication approved by the Director. Received for publication November 13, 1917.

[2] The author wishes to acknowledge the many useful suggestions made and the aid rendered during the course of this investigation by C. G. Williams, agronomist, and J. W. Ames and C. J. Schollenberger, chemist and assistant chemist, all of the Ohio station.

## Plan of Experiment 1915–1916.

A plot of soil having an area of 18 square feet was treated with green clover at the rate of 7,744 pounds per acre, to correspond to the practice of mowing a crop and allowing it to remain on the surface of the ground for some time before plowing it under. A similar area was treated with a like quantity of clover, which was spaded under. A similar experiment was conducted in a lysimeter test, each container having an area of 9 square feet and receiving an application of green clover at the rate of 17,520 pounds per acre. The loss on ignition of the moisture-free soil and clover was determined on samples taken at the beginning and end of the experiment, and the loss of organic matter calculated from these data. The clover was applied to the soil October 12, 1915, and the residue collected and soil sampled on May 5, 1916, so that the clover was exposed to the

Table I.—*Organic matter retained in soil at the end of 206 days and percentage lost from clover left on surface as compared with that spaded into the soil, 1915–16.*

| Method of application | Clover applied. | Residue on surface at end of experiment. | Organic matter. | | | |
|---|---|---|---|---|---|---|
| | | | Applied. | In residue at end of experiment. | Retained by soil. | Loss. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Percent.* |
| Clover on surface. | | | | | | |
| Field test | 2,000 | 639.2 | 1,075.4 | 360.9 | 4.1 | 66.05 |
| Lysimeter test | 2,000 | 440.1 | 1,202.8 | 302.5 | 76.0 | 68.52 |
| Clover mixed with soil. | | | | | | |
| Field test | 2,000 | | 1,075.4 | | 769.4 | 28.45 |
| Lysimeter test | 2,000 | | 1,202.8 | | 498.8 | 58.53 |

action of the weather for a period of 206 days. The figures in Table I express the loss of organic matter during the experiment of 1915–16 in a ton of green clover when applied at the rate indicated above.

## Plan of Experiment 1916–1917.

Two sets of duplicate plots, adjacent to each other and each measuring 6 by 3 feet, were spaded to a depth of 6 inches; during the spading, 1,573 grams (3.46 pounds avoirdupois) of dried and finely cut clover were thoroughly and evenly mixed with the soil of each of two plots, while the same quantity of uncut clover was spread upon the surface of each of two others, the soil having been compacted after spading. This quantity on an area of 18 square feet corresponds to 8,000 pounds or 4 tons of dry clover to the acre. Samples of both the clover used and of the soil from each plot before

adding the clover were taken and subsequently analyzed. The plots were prepared as described on November 8, 1916, and were immediately covered with a wire screen in order to prevent the clover spread on the surface from being blown away, as well as to prevent other material from being carried on to the plots. The duration of the experiment was 187 days, from November 8, 1916, to May 4, 1917, when the plots were sampled in the same manner as at first, after carefully removing the residue of clover from the surface of the two plots on which it had been spread.

The first experiment was intended to furnish data on the loss of organic matter only; in order to make the results of the second experiment of greater value, carbon and nitrogen determinations on the different samples were made instead of the determination of loss on ignition.

Analyses were made of the soil from each plot, both at the beginning and at the end of the experiment. The clover applied and the residue removed were also analyzed. The percentages of carbon and of nitrogen in the soil at the beginning and at the end of the experiment are shown in Table 2, while Table 3 gives data on the carbon

TABLE 2.—*Percentage of carbon and of nitrogen in soil to which 8,000 pounds of dry clover to the acre was added on the surface and by spading in, at the beginning and at the end of a period of 187 days.*

| Element and time of determination. | Clover spaded in. | | | Clover spread on surface. | | |
|---|---|---|---|---|---|---|
| | Plot 1. | Plot 3. | Average. | Plot 2. | Plot 4. | Average. |
| Carbon: | | | | | | |
| At beginning...... | 1.058 | 1.021 | 1.039 | 1.021 | 1.087 | 1.054 |
| At end........... | 1.148 | 1.169 | 1.158 | 1.064 | 1.041 | 1.052 |
| Nitrogen: | | | | | | |
| At beginning...... | .097 | .097 | .097 | .097 | .097 | .097 |
| At end........... | .105 | .105 | .105 | .099 | .100 | .099 |

and nitrogen in pounds per acre. The clover added contained 42.31 percent of carbon and 1.99 percent of nitrogen. From Plot 2 6,164 pounds of residue were removed, containing 29.34 percent of carbon and 1.91 percent of nitrogen, while from the corresponding Plot 4 7,568 pounds of residue were removed, containing 23 percent of carbon and 1.38 percent of nitrogen.

## RESULTS OF EXPERIMENTS.

There was very little if any loss of nitrogen during the experiment, either from the clover incorporated or left on top of the soil. Owing to the small increase in percentage of total nitrogen produced

in the soil by the clover added and to the difficulty of securing a representative sample as well as the limitations of the method for total nitrogen in soils, the slight differences shown in the table of the nitrogen recovered are well within the limits of analytical error.

TABLE 3.—*Pounds per acre of carbon and of nitrogen in soil to which 8,000 pounds of dry clover to the acre was added on the surface and by spading in, with loss from the clover at the end of 187 days.*

CARBON.

| Determination. | Clover spaded in. | | | Clover spread on surface. | | |
|---|---|---|---|---|---|---|
| | Plot 1. | Plot 3. | Average. | Plot 2. | Plot 4. | Average. |
| At beginning | 19,785 | 19,093 | 19,439 | 19,093 | 20,327 | 19,710 |
| Added in clover | 3,385 | 3,385 | 3,385 | 3,385 | 3,385 | 3,385 |
| Total | 23,170 | 22,478 | 22,824 | 22,478 | 23,712 | 23,095 |
| At end | 21,468 | 21,860 | 21,664 | 19,897 | 19,467 | 19,682 |
| Loss during period | 1,702 | 618 | 1,160 | 2,581 | 4,245 | 3,413 |
| Remaining in residue | | | | 1,809 | 1,741 | 1,775 |
| Net loss | 1,702 | 618 | 1,160 | 772 | 2,504 | 1,638 |

NITROGEN.

| Determination. | Plot 1. | Plot 3. | Average. | Plot 2. | Plot 4. | Average. |
|---|---|---|---|---|---|---|
| At beginning | 1,814 | 1,814 | 1,814 | 1,814 | 1,814 | 1,814 |
| Added in clover | 159 | 159 | 159 | 159 | 159 | 159 |
| Total | 1,973 | 1,973 | 1,973 | 1,973 | 1,973 | 1,973 |
| At end | 1,964 | 1,964 | 1,964 | 1,851 | 1,870 | 1,860 |
| Loss during period | 9 | 9 | 9 | 122 | 103 | 113 |
| Remaining in residue | | | | 118 | 104 | 112 |
| Net loss | 9 | 9 | 9 | 4 | [a]1 | 1 |

[a] Apparent gain.

However, the indications are that no appreciable loss of nitrogen occurred.

The data in Table 1 show that the organic matter in a ton of green clover when cut and allowed to remain on the surface of the soil for 206 days decreased from 1,075 pounds originally present to 361 pounds. Of the 715 pounds of organic matter that disappeared from the surface a mere trace, 4 pounds, was retained by the soil, while 711 pounds were lost through processes of decay. The rate of application and the stage of maturity of the clover used in the lysimeter test were different from those used in the field test, but the percentage loss is practically the same in both cases, being 66.05 percent for the field test and 68.52 for the lysimeter test.

The loss of carbonaceous matter expressed as elementary carbon was greater when the clover was allowed to lie upon the surface than when turned under in both the 1915–1916 and 1916–1917 experiments. The average loss shown by the two plots of 1916–1917 with

the clover on the surface was 48.38 percent, while those with the clover incorporated in the soil lost 34.26 percent of the carbon applied during the same experiment. The results of the 1916–1917 experiment are similar to those obtained in 1915–1916. Differences in season and duration of experiment would undoubtedly affect the results.

## Value of Green Manures.

Green-manure crops assimilate, concentrate, and return to the soil essential plant nutrition elements that are available for succeeding crops. The fertilizing elements thus prepared for assimilation by other crops may have a beneficial influence after the greater portion of the organic matter by which they are carried is destroyed. Half or more of the organic matter in a crop, depending upon the method employed in returning it to the soil, may be destroyed within six months, yet the beneficial effects are apparent for several years afterward. That mineral fertilizers have a decided value in crop production, whether accompanied by organic matter or not, can not be disputed. Consequently, the value of the fertility elements in a green-manure crop should not be ignored, although they originally came from the soil. Crops having high fertility value should be returned to the soil for their fertilizing constituents as well as for any theoretical value of the organic matter.

## Advantage of Feeding Crop and Applying Manure.

Data reported in Ohio station Bulletin 183 from an experiment in which 28 steers were fed on a cement floor, the duration and season of the experiment corresponding very closely to the plot experiments under discussion, indicate that almost exactly one third of the total organic matter in the feed and straw used for bedding was recovered in the manure. This experiment shows that practically as much organic matter is applied to the soil when a crop of clover is fed and the manure applied to the soil as when the crop is allowed to remain on the surface of the ground from fall until spring before being plowed under.

Eliminating the comparatively small amount of fertilizing elements lost in metabolic processes when feeding clover to farm animals and considering the organic matter only, very little would appear to be gained by plowing a clover crop under rather than feeding it and applying the manure.

# MILLING AND BAKING TESTS OF EINKORN, EMMER, SPELT, AND POLISH WHEAT.[1]

J. A. LE CLERC, L. H. BAILEY, AND H. L. WESSLING.

Wheats are classified according to Hackel as follows:

*Triticum monococcum*—Einkorn or one-kerneled wheat.
*Triticum sativum dicoccum*—Emmer.
*Triticum sativum spelta*—Spelt.
*Triticum sativum tenax vulgare*—Common wheat.
*Triticum sativum tenax durum*—Durum wheat.
*Triticum polonicum*—Polish wheat.

The einkorn used in our investigations (C. I. No. 2433) was a small grain irregular in size which did not separate readily from the chaff. It seemed much like an immature and shriveled sample of ordinary wheat. Some of the grains were so small that they contained very little endosperm.

The kernels of the emmer (Black Winter, C. I. No. 2337) which was used in this experiment were larger than ordinary wheat and in shape resembled somewhat the rye grain. It was also difficult to remove the chaff from the grain.

The sample of spelt[2] (Alstroum, C. I. No. 3264) resembled emmer quite closely in appearance of the grain; in fact, the names are sometimes confused in this country. Spelt and emmer are both used mostly as stock feed and very little for human food.

The sample of Polish wheat used was obtained from C. B. West, Sheridan, Wyo. The kernels of this sample were even larger than those of durum wheat and about twice as long as those of ordinary wheat. In appearance the kernels were flinty and of an amber color, thus resembling durum wheat. Polish wheat differs from the einkorn and spelt in that it is readily separated from the chaff, so that ordinary thrashing is all that is required to prepare the grain for the miller.

[1] Contribution from the Laboratory of Plant Chemistry of the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. Received for publication April 3, 1918.

[2] The three wheats (einkorn, emmer, and spelt) were obtained for us through the courtesy of the Office of Cereal Investigations, Bureau of Plant Industry. The emmer and spelt were supplied hull free. The sample of einkorn was hulled in the laboratory before milling.

Of the wheats, *Triticum sativum tenax vulgare* is the usual source of flour for bread and biscuits. Durum wheat is especially adapted for the manufacture of semolina used in making macaroni. The other wheats have seldom been used in the manufacture of flour. Emmer is sometimes used as a breakfast food.

The object of this experiment was to determine whether these rarer wheats could be successfully milled into good flour and whether the flours produced therefrom would make good bread. Samples of all of these wheats were milled on an Allis-Chalmers experimental flour mill, a sample of hard spring wheat being likewise milled at the same time as a check. All the samples were tempered to 13 percent of moisture over night, then scoured and tempered to 15 percent for 2 hours, and then milled so as to obtain a 65 percent patent flour. No attempt was made to obtain a straight grade of flour or to obtain a maximum flour yield.

The results of milling showed that Polish wheat and emmer have a smaller amount of bran than hard spring wheats, thus indicating a possibly larger flour yield. Even when milled on a 65 percent patent basis all of these flours (except that from spring wheat) were somewhat gray in color, although the flour from spelt was only slightly darker than that from spring wheat.

Table 1 shows the composition of the flours and gives the characteristics of the breads produced therefrom.

From this table it will be seen that flour made from spelt is more nearly like that from spring wheat in its ash, nitrogen, acidity and

TABLE 1.—*Composition of flours and characteristics of bread made from einkorn, emmer, spelt, and Polish wheat.*

COMPOSITION OF FLOURS.

| Character. | Hard spring wheat. | Einkorn. | Emmer. | Spelt. | Polish wheat. |
|---|---|---|---|---|---|
| Moisture, percent | 11.750 | 10.450 | 11.200 | 11.010 | 10.300 |
| Ash, percent | 0.393 | 0.811 | 0.783 | 0.555 | 0.848 |
| Protein (Nx 5.7), percent | 10.090 | 15.500 | 13.790 | 12.250 | 13.050 |
| Acidity, percent | 0.075 | 0.223 | 0.213 | 0.151 | 0.325 |
| Gluten, wet, percent | 27.100 | 37.700 | 44.800 | 31.700 | 34.500 |
| Gluten, dry, percent | 9.900 | 14.000 | 14.600 | 11.000 | 12.600 |
| Absorption, percent | 69.500 | 66.500 | 82.000 | 67.000 | 76.000 |
| Maximum expansion of dough, c.c. | 780 | 320 | 680 | 680 | 640 |

CHARACTERISTICS OF BREADS.

| | | | | | |
|---|---|---|---|---|---|
| Color, percent | 97.5 c.[1] | y. brown | 94 c.g.[2] | 96 c.g. | 95 g. |
| Texture, percent | 98 | 96 | 95 | 96 | 94 |
| Elasticity, percent | 99.5 | 92 | 98 | 98.5 | 99 |

[1] c = creamy. g = gray.

gluten content than the other flours. Flour from einkorn, emmer, and Polish wheat are very high in ash, acidity, and in gluten. Emmer flour showed an extremely high absorption capacity, while Polish-wheat flour was second in this respect. Flours from spelt and einkorn had approximately the same absorption as that possessed by spring-wheat flour.

When these flours were baked into bread, the bread made from the einkorn was the least desirable not only in volume but in color, elasticity, and in taste or flavor. In fact, the results obtained with einkorn might indicate that this kind of wheat is not suited to make a good yeast-risen bread. That made from emmer was somewhat better, although not equal to bread made from spring-wheat flour in color, volume, and elasticity. The Polish-wheat bread had a better color than the emmer bread, but the volume was not quite so large. The crumb, however, seemed more moist than that from other breads and in fact this bread had an elasticity almost equal to that of spring-wheat bread. The spelt bread on the other hand compared favorably in most respects to the ordinary wheat bread, except that the color was a little darker. There was no difference in taste and appearance from ordinary wheat bread.

## Summary.

1. The rarer wheats, emmer and spelt (both free of hulls) and Polish wheat, can be milled into a satisfactory flour and the flour used in baking a good loaf of bread.

2. The results obtained from einkorn (free of hulls) are not so encouraging.

3. Alstroum spelt seems particularly adapted to the production of a good flour for baking purposes.

4. Black Winter emmer flour has a very high absorption capacity.

5. In view of the well-known present deficiency in our wheat supply the use of emmer, spelt, and Polish wheat as human food (bread, breakfast cereals, etc.) should be encouraged wherever they are available. As they are not superior to the more common varieties of wheat there would be no advantage in having them replace ordinary wheats in normal times.

# COMPARATIVE SMUT RESISTANCE OF WASHINGTON WHEATS.[1]

E. F. Gaines.

## Damage Caused by Stinking Smut in the Northwest.

Washington, Oregon, and Idaho produce over 40,000,000 bushels of winter wheat annually. Stinking smut is more prevalent in the winter-wheat sections of these States than anywhere else in the United States, and probably a larger percentage of the crop is affected than on an equal acreage anywhere else in the world. It is not uncommon to find whole fields with 40 percent of smut. Several county agents in the more important winter-wheat growing counties have estimated that these three States lose in the neighborhood of 15 percent of their winter wheat by smut. This would mean a loss of 6,000,000 bushels, which are worth, at present prices, over $10,-000,000. The prevalence of smut in winter wheat seems to be increasing in spite of the most careful methods of seed treatment. This condition is causing many farmers to abandon winter wheat until some measures can be found to control smut. The elimination of winter wheat is undesirable from the standpoint of distribution of labor in seeding and harvesting and from the fact that winter wheat produces from 1 to 5 bushels per acre more than spring wheat.

## Present Methods of Smut Control.

Several methods of producing winter wheat with little or no smut are known. It has been found both by experiment and by farm practice that little or no smut is produced when the crop is seeded very early in the season, but this is not desirable on account of overdevelopment in the fall and a consequent reduction in yield. Moreover, in a dry season or when the cultivation has not been the best, the moisture in the soil in July or early August is insufficient to germinate the seed. It is impossible to sow early except on summer fallow. There is also the added expense of carrying over the seed from the previous year's crop.

Little or no smut is produced in fields that are sown abnormally

[1] Contribution from the Washington Agricultural Experiment Station, Pullman, Wash. Received for publication April 1, 1918.

late, but the weather between Thanksgiving and Christmas is so unsettled that it is often impossible to seed during this period. There is also danger of the grain freezing out when it is sown so late. Therefore, both very early and very late seeding, although eliminating smut to a large degree, may be dismissed as undesirable as a general practice. Winter wheat is normally seeded during the months of September and October in the Northwest. This has been shown by repeated experiments to be the period of maximum infection. It has been suggested that by replowing the summer fallow just prior to seeding, the wind-borne smut spores would be buried beyond the infection zone of the germinating grain and a reduction in smut would result even when the sowing was done in the normal season. This practice is untenable because the expense is prohibitive and the time is not available at this season of the year. Moreover, it leaves the soil in bad physical condition.

As none of the methods of smut control mentioned above are generally practicable, it was thought that, if a variety of wheat could be found that was immune or highly resistant to the attacks of this fungus, it would help in the elimination of this evil.

## Investigation on Resistance: Method and Material.

For the past four years the Washington station has been studying the comparative smut resistance of the most common winter wheats of the Northwest. The method employed was to blacken the seed with smut spores just before planting, and sow all the varieties on the same date, under uniform conditions, in rows 18 inches apart. A furrow was made with a small garden push plow, the seed spaced 5 to 7 inches apart therein, and covered with the same implement by plowing in the earth from each side. Enough cultivation was given to keep down weeds in spring and early summer. At harvest time each variety was pulled as it became ripe. The plants were divided into three piles as follows: Plants smut free, plants all smutted, and plants partly smutted. The number of plants in each pile was recorded, then the plants partly smutted were further divided into healthy heads and smutted heads and the number of each recorded. When a head was found that was only partially smutted, if it was more than half smutted it was put into the smutted pile; otherwise it went into the uninfected pile. Table 1 gives the sum of these counts during the past three years.

Table 1 gives the total infection distribution in tabular form of thirteen varieties during 1915, 1916 and 1917. The plantings were

TABLE 1.—*Number of plants smut free, all smutted, and partly smutted under conditions of maximum infection in 1915, 1916, and 1917, with the number of uninfected and smutted heads and the average number of heads produced by the partly smutted plants.*

| Variety. | Number of plants. | | | Number of heads on partly smutted plants. | | |
|---|---|---|---|---|---|---|
| | Smut free. | All smutted. | Partly smutted. | Not smutted. | Smutted. | Average total number per plant. |
| Turkey | 810 | 1 | 298 | 7,518 | 514 | 26.9 |
| Alaska | 35 | 0 | 8 | 101 | 17 | 14.7 |
| Fortyfold | 118 | 77 | 305 | 1,732 | 4,452 | 20 3 |
| Red Russian | 85 | 115 | 320 | 1,863 | 5,754 | 23.8 |
| Salzer's Marvel | 10 | 15 | 122 | 1,069 | 2,744 | 31.3 |
| Triplet | 77 | 266 | 539 | 2,591 | 10,690 | 24.6 |
| Winter Bluestem | 25 | 149 | 196 | 949 | 3,217 | 21.3 |
| Little Club | 50 | 304 | 54 | 233 | 997 | 22.8 |
| Jones Winter Fife | 49 | 575 | 217 | 910 | 2,842 | 17.3 |
| Hybrid 143 | 43 | 496 | 127 | 606 | 2,323 | 23.1 |
| Hybrid 123 | 17 | 244 | 214 | 630 | 4,081 | 19.1 |
| Hybrid 108 | 41 | 497 | 105 | 490 | 1,798 | 21.8 |
| Hybrid 128 | 43 | 696 | 139 | 565 | 2,467 | 21.8 |

made on November 7, October 14, and November 24, respectively. While this is later than winter wheat is usually seeded, yet the results should be comparable, for all varieties received exactly the same treatment. The large number of heads per plant is not unusual considering the cultivation they received and the fact that each plant had a space of approximately 108 square inches. Counts from an average of 575 plants of each variety or a total of 7,481 plants, of which 2,644 partly smutted plants were divided into 19,257 wheat heads and 41,896 smut heads, are given in Table 1 as the basis of the percentage comparison presented in Table 2.

This compilation has been made in order to show in easily comparable form, the susceptibility to smut of the different varieties of winter wheat. The first column, percentage of infected plants, is the sum of the plants all smutted and partly smutted in terms of percentage of the total number of plants. The third column, total percentage of smut produced, is the sum of the smut produced on both the plants partly smutted and wholly smutted. The fourth column is the percentage of smut produced in an entirely different experiment. It is based on a head count of part of one drill row in each plot of the field variety tests and is the average percentage of smutted heads produced during the last three years from treated grain. This column represents the percentage of smut produced in winter wheat under conditions as unfavorable for smut production as we are able to make them in field practice. This column was put

TABLE 2.—*Percentage of infected plants, percentage of smut on infected plants, and total percentage of loss from smut under conditions of maximum infection, together with the total loss from smut under conditions of minimum infection.*

| Variety. | Infected plants. | Smutted heads on infected plants. | Total smut produced. | Smut heads in field variety test. |
|---|---|---|---|---|
| | *Percent.* | *Percent.* | *Percent.* | *Percent.* |
| Turkey | 26.96 | 6.71 | 1.81 | 1.8 |
| Alaska | 18.60 | 14.41 | 2.69 | |
| Fortyfold | 76.40 | 77.64 | 59.32 | 3.9 |
| Red Russian | 83.65 | 82.01 | 68.61 | 3.9 |
| Salzer's Marvel | 93.20 | 75.04 | 69.93 | |
| Triplet | 91.27 | 86.93 | 79.34 | 2.5 |
| Winter Bluestem | 93.24 | 87.07 | 81.19 | 5.6 |
| Little Club | 87.75 | 97.15 | 85.14 | 8.1 |
| Jones Winter Fife | 94.17 | 93.36 | 87.92 | 4.7 |
| Hybrid 143 | 93.54 | 95.79 | 89.60 | 9.4 |
| Hybrid 123 | 96.42 | 93.28 | 89.94 | 8.5 |
| Hybrid 108 | 93.62 | 96.27 | 90.12 | 6.7 |
| Hybrid 128 | 95.10 | 96.90 | 92.15 | 8.6 |

in to show that careful seed treatment and crop rotation do not eliminate smut, although it is less than is produced by the average farmer on summer fallow, according to the estimates of county agricultural agents.

Turkey (Wash. No. 326) is the only highly resistant wheat of commercial importance in the list. Even after a plant was infected 93.29 percent of the normal yield of wheat was produced. In contrast with this, Red Russian, the variety most commonly grown in the moister sections of the State, produced only 17.99 percent of the normal yield after it was once infected. Moreover, only 26.96 percent of the Turkey plants were infected, while 83.66 percent of the Red Russian plants showed infection. Little Club and Jones Winter Fife are much less resistant even than Red Russian. It will be noted that 87.75 percent of the plants of Little Club were infected and that these produced only 2.85 percent of the normal yield of grain. Jones Winter Fife had a higher percentage of infection (94.17 percent), but more grain was recovered from the infected plants (6.65 percent). The same phenomenon is shown with Turkey and Alaska, the two distinctly resistant strains. Turkey has 8.36 percent more infected plants, but recovers 7.7 percent more grain from the infection than does Alaska.

## FACTORS CAUSING VARYING DEGREES OF RESISTANCE.

From these irregularities it would seem probable that there are two distinct factors that control the resistance of wheat to smut. One prevents infection, as is seen by the large variation in percent-

age of infected plants between Alaska and Hybrid 123. The other prevents smut-balls from forming, as is seen by the large variation in quantity of wheat produced on infected plants of Turkey and Little Club. If these two factors exist, one preventing infection and one preventing the smut from fruiting after infection, there is a high degree of correlation between them, for in general low percentage of infection is followed with a low percentage of smut-balls produced on the infected plants. The converse is also true. High percentage of infection is associated with a high percentage of smut produced on the infected plants.

Little is known concerning the actual process of infection. The assumption that all infected plants would produce at least one smut-ball may be wrong. We have no means of determining this point. Perhaps many infection threads must enter the host cells and there fuse in order to live and reproduce smut spores at harvest time. It may be, as Kirchner[2] suggests, that a cell sap of slightly higher acid content is associated with a high degree of smut resistance.

Whatever the reason, there is a very marked difference in the resistance to smut of some of the different varieties tested. Under conditions of maximum infection Turkey was reduced in yield 1.8 percent by smut, while hybrid 128 was reduced 92.15 percent under the same conditions.

# AGRONOMIC AFFAIRS.

## MEMBERSHIP CHANGES.

The membership reported in the April issue was 648. Since that time 6 new members have been added, 4 have resigned, and 1 has died, a net gain of 1 and a present membership of 649. The names and addresses of the new members, names of those resigned and deceased, and such changes of address as have been reported are as follows. A list is also appended of those whose addresses are unknown to the Secretary-Treasurer, recent letters sent to them at the latest reported addresses having been returned unclaimed. Any one who can furnish complete addresses of any of these persons will confer a favor on the Secretary-Treasurer if they will make this information available to him.

[2] von Kirchner, O. *In* Zeitschr. Pflanzenkrank. 26: 17–25. Stuttgart, Apr. 22, 1916. *Reviewed in* Internat. Rev. Sci. Pract. Agr., vol. 7, July, 1916.

### New Members.

Buenaventura, Linea Rueda, 97 Antiguo Entre 8 y 10, Vedado, Habana, Cuba.
Cooper, M. L., Merryville, La.
Cowles, Henry C., University of Chicago, Chicago, Ill.
Garber, R. J., University Farm, St. Paul, Minn.
Johnson, T. C., Va. Truck Station, Norfolk, Va.
Kirk, N. M., Bureau of Soils, Washington, D. C.

### Members Resigned.

Bell, N. Eric,
Lathrop, E. C.,
Packard, W. E.
Miles, Frank C.,

### Member Deceased.

Anderson, A. C.

### Changes of Address.

Jones, J. W., Biggs Rice Field Station, Biggs, Cal.
Krall, J. A., County Agent, Manchester, Iowa.
Moore, Harvey L., c-o Thos. S. Newell, R. D., Pemberton, N. J.

### Addresses Unknown.

Bruce, O. C.,
Currey, Hiram M.,
Douglas, J. P.,
Freeman, Ray,
Shinn, E. H.
Kent, W. A.,
Kenworthy, Chester,

## ROLL OF HONOR.

Since the last issue, the names of several members of the Society who are serving their country in its military forces have been reported. The complete list reported to date is published herewith. The editor will appreciate the favor if those who know of other members of the Society whose names should be added will report them to him, as well as items of interest regarding any of these men.

Brunson, A. M.,
Burnett, Grover,
Cates, H. R.,
Chapman, James E.,
Childs, R. R.,
Downs, E. E.,
Ellison, A. D.,
Gilbert, M. B.,
Graham, E. E.,
Gray, Samuel D.,
Head, A. F.,
Holland, B. B.,
Jensen, O. F.,
Karlstad, C. H.,
Kime, P. H.,
Moomaw, Leroy,
Palmer, H. Wayne,
Purington, J. A.,
Towle, R. S.
Quigley, J. V.,
Ratliffe, Geo. T.,
Raymond, L. C.,
Richards, Phil E.,
Schneiderhan, F. J.,
Schoonover, W. R.,
Scott, Herschel,
Smith, John B.,
Tabor, Paul,

## NOTES AND NEWS.

Carleton R. Ball, for the past several years in charge of work with wheat in the western half of the United States in the Office of Cereal Investigations, has succeeded M. A. Carleton as chief of that office.

Recent changes in the Office of Dry-Land Agriculture, U. S. Department of Agriculture, involve the transfer of J. M. Stephens, superintendent of the Judith Basin Substation, Moccasin, Mont., to the superintendency of the Northern Great Plains Field Station, Mandan, N. Dak., *vice* W. A. Peterson. P. V. Cardon, formerly of the Office of Cotton Investigations, has succeeded Mr. Stephens at Moccasin.

Four field representatives of the Office of Cereal Investigations, U. S. Department of Agriculture, resigned recently to engage in farming on their own account. With their former positions, they are E. L. Adams, superintendent of the Biggs Rice Field Station, Biggs, Cal.; L. R. Briethaupt, superintendent of the field station at Burns, Oregon; N. C. Donaldson, of the Judith Basin Substation, Moccasin, Mont.; and J. D. Morrison, of the Highmore substation, Highmore, S. Dak. Mr. Adams has been succeeded at Biggs by J. W. Jones, former superintendent of the Nephi (Utah) substation, who in turn has been succeeded by A. F. Bracken. J. H. Martin, formerly of the Bellefourche Experiment Farm, Newell, S. Dak., is the new superintendent at Burns, Ore.

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# THE TRIANGLE SYSTEM FOR FERTILIZER EXPERIMENTS.[1]

OSWALD SCHREINER and J. J. SKINNER.

## INTRODUCTION.

Fertilizer experimentation for determining the specific needs of any particular soil type or crop is one of the big problems before American agriculturists. It is not our purpose here to dwell upon the shortcomings of many efforts in this direction, but we must say in passing that the popular conception, even among agricultural specialists, that this problem can be solved by a soil, or a plant, or an ash analysis is a vain hope which has not and cannot be realized. Much can be learned from such work, but not the fertilizer requirement of the soil or plant to increase the yield, quality, appearance, or freedom from disease. Experimentation direct with soil and plant have thus far been the only means to give this answer and in this connection the soil has nearly always been ignored and the fertilizer combinations tested have always been so restricted that a full and complete answer to this complicated question is yet to be reached. There have been some excellent fertilizer experiments, especially the long-term systems at several of the experiment stations, but by far the greater number of tests made from time to time on this land or that land, this crop or that crop, the country over, have been so lacking in plan and in thoroughness that they have served only a temporary purpose. How-

[1] Contribution from the Office of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Presented by the senior author, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917 Received for publication April 3, 1918.

ever useful they may have been, they offer little for the interpretation of the broad fundamental questions of soil fertilization and crop needs. It is not our purpose to disparage the many well-planned experiments which are in successful operation. Rather, we wish to call to the attention of those planning further work, a system of fertilizer experimentation which, with proper and careful attention to soil differences as far as they can be mapped in advance or in the course of the experiment, ought to give a sufficiently comprehensive basis for proper interpretation and easy presentation and handling of the results.

In the following discussion the triangle system is outlined as we have used it in our problems and as others have employed it in similar or related lines, largely as a suggestion to other workers who may not as yet have seen its advantages.

When it is desired to test the effect of all possible ratios of the fertilizer elements, $P_2O_5$, $NH_3$, and $K_2O$, the triangle system has been found to be admirably suited. Graded in 10 percent stages there are in this experiment 66 tests, or graded in 20 percent stages there are 21 tests, involving the fertilizer elements singly, in combinations of two, and in combinations of three.

To bear in mind these various ratios and the results obtained therewith is difficult. In so comprehensive an experiment as this the material must be reduced to a workable basis so that the various phases of the results can readily be presented and the proper correlations and comparisons made.

## Use of the Triangular Diagram.

A triangular diagram is shown in figure 28. It is an equilateral triangle in which the extreme points of the angles represent 100 percent[2] respectively, of the constituents, $P_2O_5$, $NH_3$, and $K_2O$, as shown in the diagram. Each side of the triangle is divided into ten equal parts and lines are drawn connecting these points.[3]

In the diagram, for the sake of ready reference, the intersections of these lines have been numbered. If we consider the line representing the base of the triangle, it is obvious that the point which represents 100 percent $K_2O$ (56 in the diagram) represents at the same time 0 percent $NH_3$, and the point which represents 100 percent $NH_3$

[2] The term "100 percent," as here used, refers to the maximum quantity of a single fertilizer constituent chosen for the experiment.

[3] Such diagrams for physical-chemical work, giving still finer rulings, namely, 100 to each line, can be purchased from the Cornell Cooperative Society, Ithaca, N. Y.

(66) likewise represents 0 percent $K_2O$. If we take a point half way between these two points (61) we have a mixture of the two salts in equal proportions; i. e., a mixture of the salts represented by that point will be 50 percent $K_2O$ and 50 percent $NH_3$. Similarly, point 16 represents 50 percent $K_2O$ and 50 percent $P_2O_5$, and point 21 represents 50 percent $NH_3$ and 50 percent $P_2O_5$.

If we take a point nearer to either of the corners, we will have a higher percentage of one and a correspondingly lower percentage of the other. For instance, at point 59 the composition is 70 percent $K_2O$ and 30 percent $NH_3$; at 29 it is likewise 70 percent $K_2O$, but 30 percent $P_2O_5$; at 64 it is 20 percent $K_2O$ and 80 percent $NH_3$; at 45 it is likewise 80 percent $NH_3$ but 20 percent $P_2O_5$.

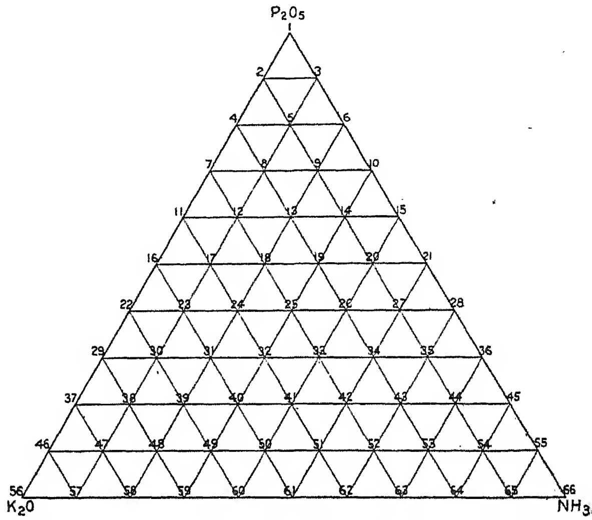


FIG. 28. Triangular diagram with the points numbered, representing the 66 fertilizer combinations in 10 percent stages.

As stated above, points on the base line 56–66 represent mixtures containing no $P_2O_5$. The next line above this, namely 46–55, represents mixtures containing throughout 10 percent $P_2O_5$, but varying amounts of the other two constituents. Similarly the line 37–45 represents throughout 20 percent mixtures of $P_2O_5$; line 29–36, 30 percent mixtures of $P_2O_5$, and so on upward until point 1, the apex of the triangle, is reached, where the composition is 100 percent $P_2O_5$ as already explained. Similarly, points on the line 1–66 represent 0 percent $K_2O$; line 2–65 represents 10 percent $K_2O$ but varying amounts of $P_2O_5$ and $NH_3$, and so on until at point 56 the composition is 100 percent $K_2O$. Likewise points on the line 1–56 represent 0 percent $NH_3$; line 3–57 represents 10 percent $NH_3$, but varying amounts of $P_2O_5$ and $K_2O$, and so on until at point 66 the composition is 100 percent $NH_3$. It is therefore obvious that any point

within the triangle represents a 100 percent mixture composed of three constituents, its position in the triangle being determined by the composition. For instance, point 12, being on the 60 percent phosphate line represents that composition of $P_2O_5$, namely 60 percent, and being at the same time on the 10 percent $NH_3$ line and the 30 percent $K_2O$ line it represents 10 percent and 30 percent of these constituents respectively. The composition of the mixture represented by this point is therefore $P_2O_5$ 60 percent, $NH_3$ 10 percent, and $K_2O$ 30 percent, i. e., the composition of the fertilizer mixture is 60–10–30. Similarly the point 34 represents a mixture of the composition $P_2O_5$ 30 percent, $NH_3$ 50 percent, $K_2O$ 20 percent, or a fertilizer composition of 30–50–20.

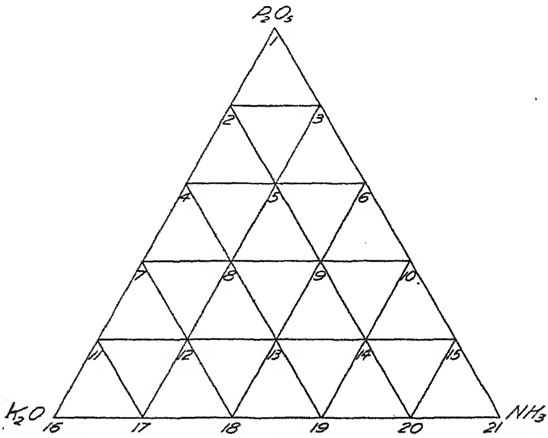


FIG. 29. Triangular diagram with the points numbered, representing the 21 fertilizer combinations in 20 percent stages.

It is of course evident that any other percentage composition or ratio of fertilizers could likewise be represented on such a diagram. Commercial brands can be represented on such a diagram by reducing the sum of the commercial percents to a basis of 100, thus an 8–4–4 fertilizer becomes 50–25–25. This point lies halfway between 18 and 19. Similarly a 10–2–2 fertilizer becomes 72–14–14 and lies between 8 and 9 on the diagram. For accurately locating such points, the finely ruled and subdivided paper referred to in the footnote should be used.

In stating the percentage composition of the fertilizer mixtures in such work, the figures are always given in the order—$P_2O_5$, $NH_3$, and $K_2O$ as shown above. The symbols $P_2O_5$, $NH_3$, and $K_2O$ are used in conformity with fertilizer practice, even when the nitrogen, for instance, is in the nitrate form.

The triangle therefore represents single fertilizer constituents at the apices or vertices, mixtures of any two constituents along the

boundary lines of the triangle, and mixtures of all three constituents within the triangle.

In Table 1 is given the composition represented by each of the 66 points in the diagram.

TABLE 1.—*Sixty-six possible ratios of the three fertilizer constituents, $P_2O_5$, $NH_3$, and $K_2O$ in 10-percent stages.*

| Point No. | Ratio or percentage composition. | | | Point No. | Ratio or percentage composition. | | | Point No. | Ratio or percentage composition. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_2O_5$. | $NH_3$. | $K_2O$. | | $P_2O_5$. | $NH_3$. | $K_2O$. | | $P_2O_5$. | $NH_3$. | $K_2O$. |
| 1 | 100 | 0 | 0 | 23 | 40 | 10 | 50 | 45 | 20 | 80 | 0 |
| 2 | 90 | 0 | 10 | 24 | 40 | 20 | 40 | 46 | 10 | 0 | 90 |
| 3 | 90 | 10 | 0 | 25 | 40 | 30 | 30 | 47 | 10 | 10 | 80 |
| 4 | 80 | 0 | 20 | 26 | 40 | 40 | 20 | 48 | 10 | 20 | 70 |
| 5 | 80 | 10 | 10 | 27 | 40 | 50 | 10 | 49 | 10 | 30 | 60 |
| 6 | 80 | 20 | 0 | 28 | 40 | 60 | 0 | 50 | 10 | 40 | 50 |
| 7 | 70 | 0 | 30 | 29 | 30 | 0 | 70 | 51 | 10 | 50 | 40 |
| 8 | 70 | 10 | 20 | 30 | 30 | 10 | 60 | 52 | 10 | 60 | 30 |
| 9 | 70 | 20 | 10 | 31 | 30 | 20 | 50 | 53 | 10 | 70 | 20 |
| 10 | 70 | 30 | 0 | 32 | 30 | 30 | 40 | 54 | 10 | 80 | 10 |
| 11 | 60 | 0 | 40 | 33 | 30 | 40 | 30 | 55 | 10 | 90 | 0 |
| 12 | 60 | 10 | 30 | 34 | 30 | 50 | 20 | 56 | 0 | 0 | 100 |
| 13 | 60 | 20 | 20 | 35 | 30 | 60 | 10 | 57 | 0 | 10 | 90 |
| 14 | 60 | 30 | 10 | 36 | 30 | 70 | 0 | 58 | 0 | 20 | 80 |
| 15 | 60 | 40 | 0 | 37 | 20 | 0 | 80 | 59 | 0 | 30 | 70 |
| 16 | 50 | 0 | 50 | 38 | 20 | 10 | 70 | 60 | 0 | 40 | 60 |
| 17 | 50 | 10 | 40 | 39 | 20 | 20 | 60 | 61 | 0 | 50 | 50 |
| 18 | 50 | 20 | 30 | 40 | 20 | 30 | 50 | 62 | 0 | 60 | 40 |
| 19 | 50 | 30 | 20 | 41 | 20 | 40 | 40 | 63 | 0 | 70 | 30 |
| 20 | 50 | 40 | 10 | 42 | 20 | 50 | 30 | 64 | 0 | 80 | 20 |
| 21 | 50 | 50 | 0 | 43 | 20 | 60 | 20 | 65 | 0 | 90 | 10 |
| 22 | 40 | 0 | 60 | 44 | 20 | 70 | 10 | 66 | 0 | 100 | 0 |

In Plate 5 the composition of the 66 ratios varying in 10-percent stages are shown as circles with red, black, and white segments to represent visually the proportions of $P_2O_5$, $NH_3$, and $K_2O$.

### PREPARATION OF THE FERTILIZER MIXTURES VARYING IN 10-PERCENT STAGES.

In order to make clear the manner of preparing fertilizer mixtures for such an experiment, let us assume that a test of acid phosphate, sodium nitrate, and potassium chloride is to be made, that the plats are to be 100 square feet, and that the fertilizers are to be applied at the rate of 50 pounds per acre of the active fertilizer constituents. This means that the sum total of $P_2O_5$, $NH_3$, and $K_2O$ will be in all cases 50 pounds per acre. As the size of the plats in these experiments is 100 square feet, it becomes necessary to calculate the quantity of each fertilizer required in the total of 66 fertilizer combinations so as to obtain the proper quantity and proper ratio for each plat.

Suitable containers are used for holding these fertilizer combinations until required for use in the field. These are numbered from 1 to 66, corresponding with the numbers of the plats in the experiment. These containers, for a small experiment like this, are set in the form of a triangle, as shown in the diagram of Plate 5. The addition of the respective analyzed fertilizer substances is thus made as follows:

*Acid phosphate.*—If the acid phosphate analyzed 14.0 percent $P_2O_5$ and the application is to be at the rate of 50 pounds of $P_2O_5$ per acre, then 357.15 pounds of the acid phosphate will be required. For a plat of 100 square feet, 0.8175 pound or 370.3 grams will be required. This, then, is the quantity to be put into container No. 1. The next row of containers, Nos. 2 and 3, is to have only 90 percent of this quantity (45 lbs. $P_2O_5$ per acre), namely, 333.3 grams. The next row of containers is to have only 80 percent of the full quantity (40 lbs. $P_2O_5$ per acre), namely, 296.2 grams. This gradation of the quantity of acid phosphate which is to be weighed out and put into the respective containers is best shown by the figures in Table 2.

TABLE 2.—*Grams of acid phosphate (14 percent $P_2O_5$) required in different fertilizer mixtures.*

| Fertilizer container along line in Plate 5. | Quantity of acid phosphate, 14 percent $P_2O_5$. | Fertilizer container along line in Plate 5. | Quantity of acid phosphate, 14 percent $P_2O_5$. |
|---|---|---|---|
| | *Grams.* | | *Grams.* |
| 1 | 370.3 | 22–28 | 148.1 |
| 2–3 | 333.3 | 29–36 | 111.1 |
| 4–6 | 296.2 | 37–45 | 74.1 |
| 7–10 | 259.3 | 46–55 | 37.0 |
| 11–15 | 222.2 | 55–66 | none |

TABLE 3.—*Grams of sodium nitrate (16.3 percent $NH_3$) required in different fertilizer mixtures.*

| Fertilizer container along line in Plate 5. | Quantity of sodium nitrate, 16.3 percent $NH_3$. | Fertilizer container along line in Plate 5. | Quantity of sodium nitrate, 16.3 percent $NH_3$. |
|---|---|---|---|
| | *Grams.* | | *Grams.* |
| 66 | 319.0 | 15–60 | 127.6 |
| 55–65 | 287.1 | 10–59 | 95.7 |
| 45–64 | 255.2 | 6–58 | 63.8 |
| 36–63 | 223.3 | 3–57 | 31.9 |
| 28–62 | 191.4 | 1–56 | none. |
| 21–61 | 159.5 | | |

*Sodium nitrate.*—If the sodium nitrate analyzes 16.3 percent $NH_3$,

306.7 pounds will be required to have 50 pounds $NH_3$ per acre. For the plat of 100 square feet this will be 0.7041 pound or 319.0 grams. Container No. 66 will therefore receive this full quantity. Containers Nos. 55 and 65 receive only 90 percent of this, 287.1 grams, and so on for other lines of containers according to the figures in Table 3.

TABLE 4.—*Grams of potassium chloride (51 percent $K_2O$) required in different fertilizer mixtures.*

| Fertilizer container along line in Plate 5. | Quantity of potassium chloride 51 percent $K_2O$. | Fertilizer container along line in Plate 5. | Quantity of potassium chloride 51 percent $K_2O$. |
|---|---|---|---|
| | *Grams.* | | *Grams.* |
| 56 | 101.9 | 11–62 | 40.8 |
| 46–57 | 91.7 | 7–63 | 30.6 |
| 37–58 | 81.5 | 4–64 | 20.4 |
| 29–59 | 71.3 | 2–65 | 10.2 |
| 22–60 | 61.1 | 1–66 | none. |
| 16–61 | 50.9 | | |

*Potassium chloride.*—If the potassium chloride analyzed 51 percent $K_2O$, then 98 pounds of chloride are required for an application of 50 pounds of $K_2O$. For the plat of 100 square feet this is 0.2249 pound or 101.9 grams. The various containers will receive the quantities specified in Table 4.

TABLE 5.—*Quantity of fertilizers to be applied per acre at the rate of 100 pounds of the sum of $P_2O_5$, $NH_3$, and $K_2O$, in 20-percent stages.*

| Fertilizer No. | Pounds of acid phosphate, 16 percent $P_2O_5$. | Pounds of sodium nitrate, 19 percent $NH_3$. | Pounds of potassium sulfate, 50 percent $K_2O$. |
|---|---|---|---|
| 1 | 625 | 0 | 0 |
| 2 | 500 | 0 | 40 |
| 3 | 500 | 105 | 0 |
| 4 | 375 | 0 | 80 |
| 5 | 375 | 105 | 40 |
| 6 | 375 | 210 | 0 |
| 7 | 250 | 0 | 120 |
| 8 | 250 | 105 | 80 |
| 9 | 250 | 210 | 40 |
| 10 | 250 | 316 | 0 |
| 11 | 125 | 0 | 160 |
| 12 | 125 | 105 | 120 |
| 13 | 125 | 210 | 80 |
| 14 | 125 | 316 | 40 |
| 15 | 125 | 421 | 0 |
| 16 | 0 | 0 | 200 |
| 17 | 0 | 105 | 160 |
| 18 | 0 | 210 | 120 |
| 19 | 0 | 316 | 80 |
| 20 | 0 | 421 | 40 |
| 21 | 0 | 526 | 0 |

### Preparation of the Fertilizer Mixtures Varying in 20-Percent Stages.

For larger experiments in the field a smaller number of plats may be considered more practical. For this purpose the variations are placed at 20 percent, as shown in figure 29. Otherwise the system is the same as that described for the 10-percent stages. The manner of preparing the fertilizer mixtures and the character of the container naturally varies with the size of the plats to be treated. Table 5 shows these 21 mixtures based on the usual composition of the commercial fertilizer material used. A similar table is readily constructed for any other analysis. The table is put on an acre basis; if the plat is one-tenth acre in size, one-tenth of the quantity is taken; if one-twentieth, one-twentieth of the quantity is taken, etc. The table is likewise based on an application of 100 pounds of the active fertilizer constituents. If 50 pounds are to be applied half of the quantity is taken, if 200 pounds is to be applied, twice the quantity in the table is taken, and so on.

### The Triangle System in Nutrient Solution Studies.

In nutrient solution work the triangle has been found to be very useful, and it was in the successful prosecution of this work that the system originated.[4] The experiments comprised the 66 cultures mentioned, using the pure, soluble salts $CaH_4(PO_4)_2$, $NaNO_3$, and $K_2SO_4$ in the proportions required by the system and with a total concentration in each culture of 80 parts per million of $P_2O_5$, $NH_3$, and $K_2O$. Figure 30 represents the green weight of wheat plants in grams obtained in such an experiment, recorded at the proper place in the diagram according to the nutrient solution in which it was grown. This is shown to illustrate the orderly and concise way in which the 66 different experiments are unified and presented to the experimenter for intelligent interpretation. A graphic representation of the numbers in figure 30 is given in figure 31. In this diagram the area of the circle is proportional to the numbers of figure 30 and is made by finding the radius corresponding to these numbers as areas of a circle according to the formula: $A = \frac{R^2\pi}{4}$ for which $R$ can either be calculated or taken from a table of such values to be found in many books. Notice how the numerous results present the story of the experiment as a whole, the relative values of the individual salts, the relative values of the two constituents as shown by the outlines of the triangle, and

[4] Schreiner, Oswald, and Skinner, J. J. Ratio of phosphate, nitrate, and potassium on absorption and growth. *In* Bot. Gaz., 50: 1–30. 1910.

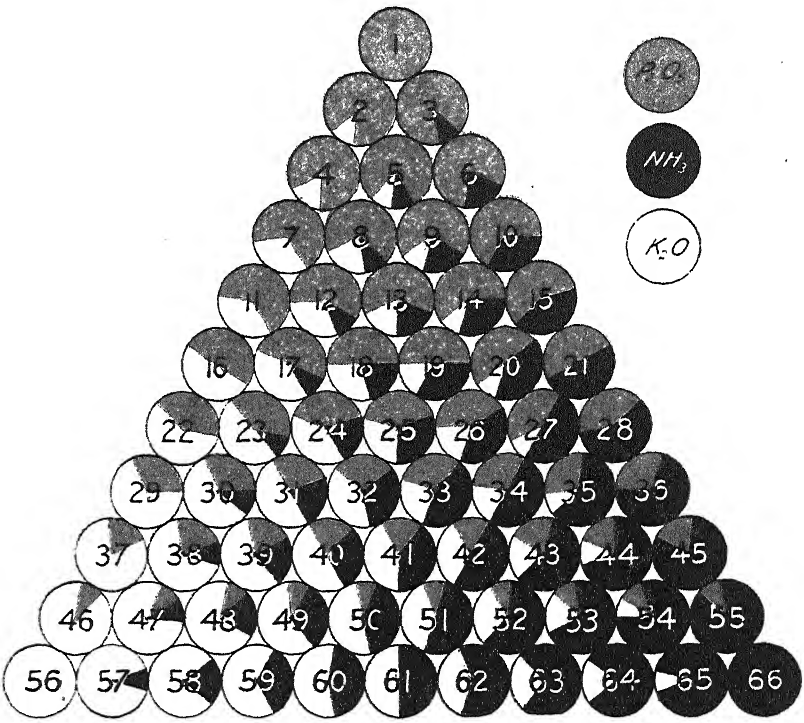


Plate 5. Triangular diagram showing the 66 fertilizer mixtures in 10 percent stages of variation, as indicated by the colors, black, white and red.

the relative values of the three constituents combined. Within the latter group it is at once apparent that the largest growth is in the middle of the lower half of the triangle as a whole. This is the region of greatest growth and these are the culture solutions in which the ratios are best suited for plant development.

A still further illustration of the usefulness of such a diagram becomes apparent when the composition of the crop grown, the ash constituents, protein content, starch content, or any other analytical figure

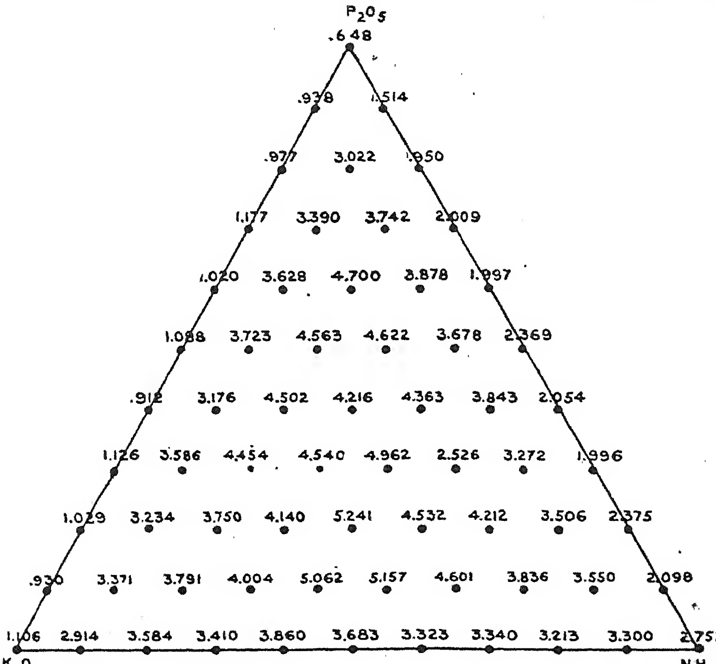


FIG. 30. Diagram showing method of recording the results in figures at the proper place on the diagram. Wheat in solution culture.

such as alkaloidal content, etc., is considered in relation to fertilizer practice or influence. For instance, in the above nutrient culture experiment, the 66 ratios of $P_2O_5$, $NH_3$, and $K_2O$ were analyzed after the plants had grown in them for a period of days so as to determine the changes which had taken place in the ratio of the constituents and thus arrive at the ratio which the plants had absorbed. For the three constituents this amounted to 198 determinations and with the original 198 figures and the 198 figures giving the absorbed constituents make a total of 594 individual figures. To obtain a clear conception of what was going on by an interpretation of the analytical results

would tax the mind of anyone to distraction. Here the triangular diagram serves a useful and necessary purpose. In figure 32 the black dots give the original composition in $P_2O_5$, $NH_3$, and $K_2O$, the small circles the composition of the solution after growth, the arrow points the composition of nutrients removed by the growing plant. Notice the unity presented by this representation of these multitudinous and otherwise unintelligible results. The arrows all point to a definite region, that is, the plants, no matter in what solution they were growing, at least attempted to get the composition best suited for their development and this lies in the middle of the triangle, corresponding with the area of greatest growth shown in figures 30 and 31.

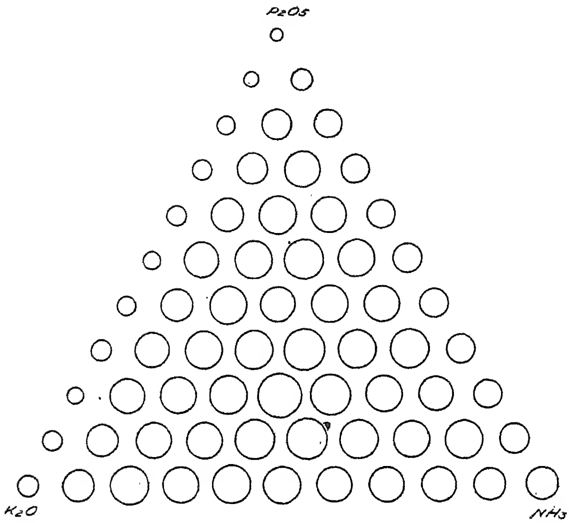


FIG. 31. Diagram showing method of recording the results diagrammatically as areas of circles at the proper points in the diagram same as figure 30. The largest circles indicate the regions of greatest growth.

In our experiments, as is well known, the principal purpose was a study of the influence of certain toxic organic compounds on the growth and on nutrition. For this purpose a second set of 66 cultures is treated with a certain definite quantity of the substance in each culture, and comparison with the corresponding normal culture is then made. In this way the influence of the substance on character and extent of growth, and influence of the fertilizer in overcoming toxicity, is then studied. Such influence is shown in figure 33, wherein the area of greatest growth is shown diagrammatically as it occurred under the influence of different toxic substances, shifting this from the normal in one direction or the other.[5] The significant fact is that

[5] Schreiner, Oswald, and Skinner, J. J. Some effects of a harmful organic soil constituent. *In* Bot. Gaz., 50: 161–181. 1910.

Schreiner, Oswald, and Skinner, J. J. The toxic action of organic compounds as modified by fertilizer salts. *In* Bot. Gaz., 54: 31–48. 1912.

while the region of greatest growth in the case of cumarin is displaced toward the higher phosphate region of the triangle, this is also the fertilizer constituent which more than any other is antitoxic to cumarin; similarly, potash appears antitoxic to quinone and nitrate to vanillin.

These characteristics are brought out by a system of grouping the individual culture results, according to those which contain, for in-

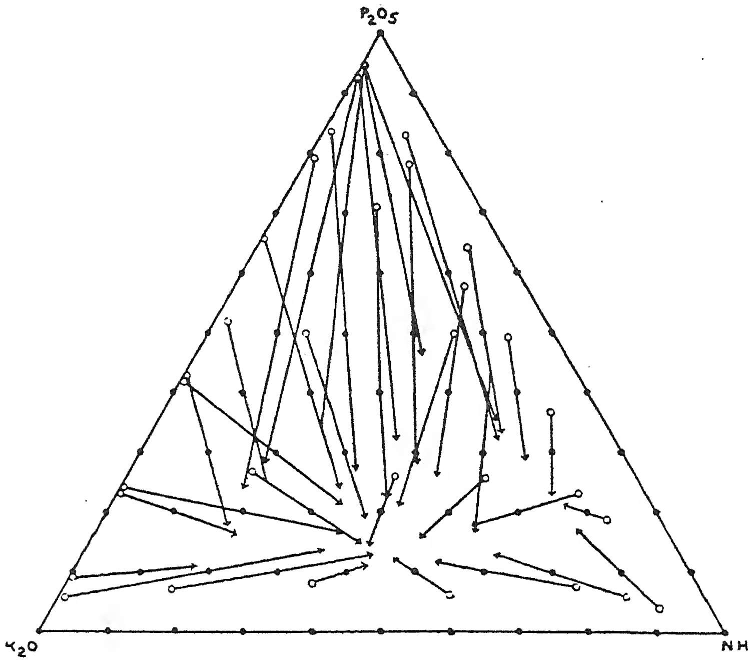


FIG. 32. Diagram showing the ratio of the original, the final, and the ratio of the loss of $P_2O_5$, $NH_3$, and $K_2O$ from the culture solution. The dots indicate the ratio of the constituents in the original solution; the circles show the ratio of the constituents in the solution after growth; and the arrows show the ratio of the decrease.

stance, more than 50 percent phosphate, or more than 50 percent nitrate, or more than 50 percent potash, as shown respectively by the dotted lines in figure 34, where the results for cumarin are presented. The cultures included as mainly phosphatic are best seen by reference to figure 28 or plate 5. They are those comprised in the sub-triangle 1–16–21. Similarly, the mainly nitrogenous are those included in the sub-triangle 66–21–61, and the mainly potassic those included in the sub-triangle 56–61–16. From figure 34 it is apparent that in the

mainly phosphatic cultures the cumarin is without effect or that the phosphate has had an antitoxic affect.

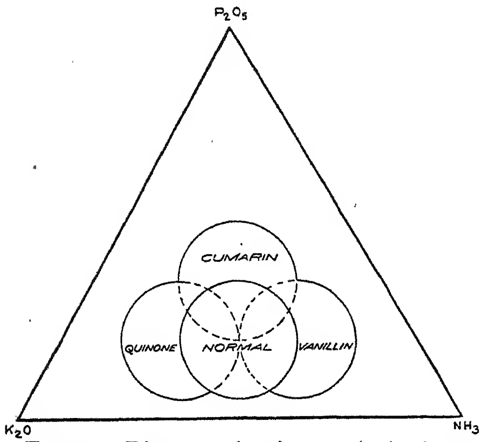


FIG. 33. Diagram showing method of representing the region of greatest growth under different conditions.

There is still another way of handling the data which confirms conclusions reached in this manner, or brings out new relationships and that is to add up the cultures along lines and obtain an average result for each line. For instance, in figure 35, the bottom line contains no phosphate, while the next lines contain consecutively 10, 20, 30, 40, 50, 60, 70, 80, 90 percents and 100 percent phosphate. The relative growths along these various phosphate lines in the case of cumarin arrange themselves in an orderly fashion with increase in phosphate.

Harris[6] has used our triangular system in studying the effect of alkali salts on the germination and the growth of plants. Harris used the salts in 25-percent stages as shown in figure 36, which is taken from his article. Besides the combination sodium-chloride-sulfate-carbonate he used a number of other salts and combinations. The use

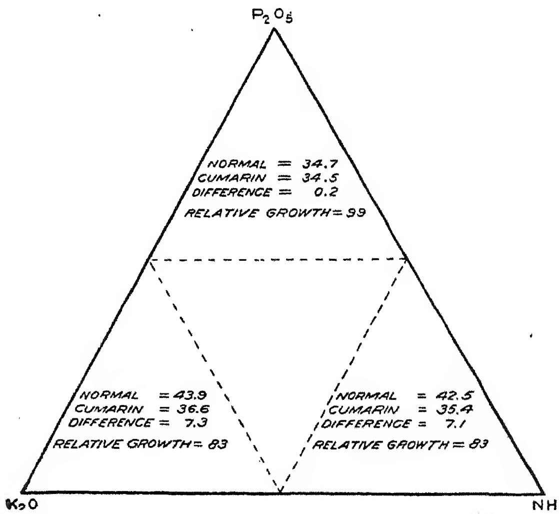


FIG. 34. Diagram showing the method of grouping cultures according to the prevailing fertilizer element.

[6] Harris, F. S. Effect of alkali salts in soils on the germination and growth of crops. *In* Jour. Agr. Research, v. 5, no. 1, p. 1–53. 1915.

of the system in 25-percent stages has one rather serious drawback in certain work on account of the fact that the combinations of all three constituents together are rather limited, in fact confined to three cultures. For the purpose used this may have been permissible, but for a fertilizer or nutrition study these 25-percent variations, in our opinion, are not as suitable as the 20-percent stages, which give six combinations containing the three constituents. Figure 36 illustrates the composition of the solutions of salt mixtures by shading instead of by colors as in Plate 5.

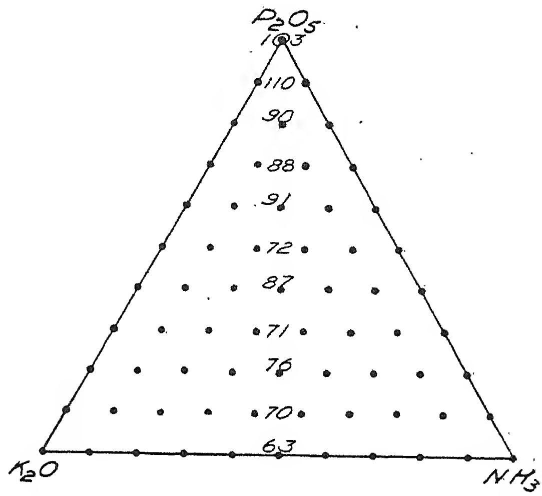


FIG. 35. Diagram showing the method of grouping according to lines of cultures containing a constant amount of any one fertilizer element. Shows the influence of phosphate in overcoming the toxic effect of cumarin.

Harris further used the diagram in representing his results in a way which is worthy of further consideration and is shown in figure 37, taken from his article. He represents his cultures by small circles arranged in the triangle form according to the composition. In the circle dots represent the number of plants germinated, and a dash the amount of dry matter produced. The diagram therefore shows at a glance the composition of the salt mixtures, the germination obtained, and the dry weight of the crop for any one concentration. Each concentration of salts is represented by another diagram and the series gives a very intelligent and comprehensive view of the results he obtained in his experiment. In the particular illustration here shown it becomes readily apparent that with increasing concentration, germination is interfered with, and that this shows itself first in the $(NH_4)_2CO_3$ section, and later also in the $K_2CO_3$ section, with the least effect in the $Na_2CO_3$ section. Similar results are apparent in the growth line in the series of diagrams. This is a striking illustration of the varied usefulness of having a definite fundamental plan in the experiments which permits handling complicated results in a

simple manner, both for the purpose of experimentation, recording the results, and presenting them in a clear, concise, and logical way to others.

This triangular system has been used and amplified by Tottingham,[7] while working at the Johns Hopkins University, in his rather com-

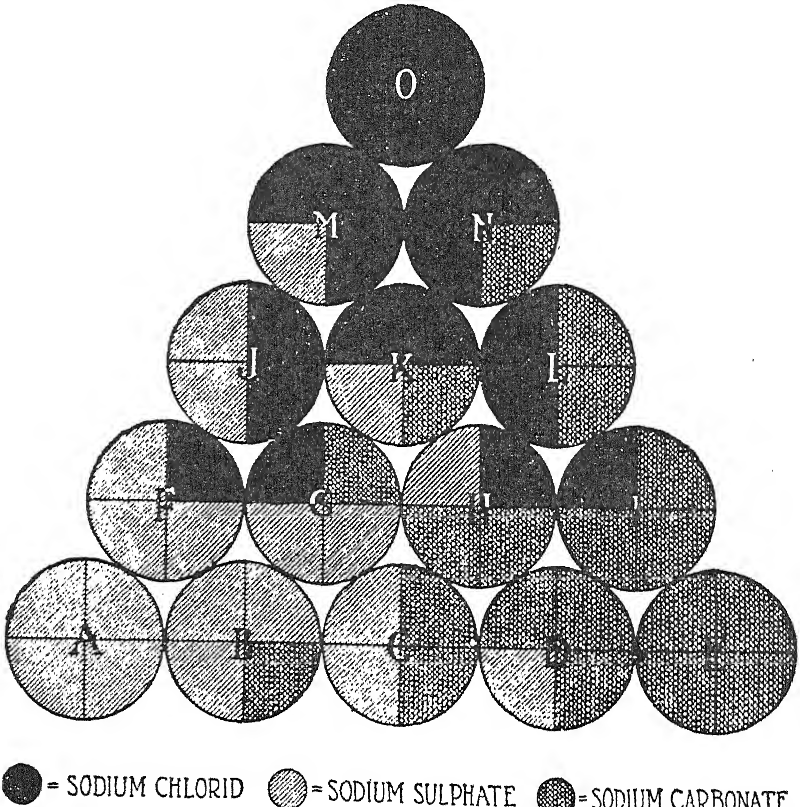


FIG. 36. Diagram showing percentage of salts, mixtures, and their position in the diagrams of experimental sets, as used by Harris. Variations in 25-percent stages.

prehensive physiological study of nutrient solutions, for the details of which the reader is referred to the original article. Likewise Shive,[8] in following up this subject at the same institution, used the

[7] Tottingham, W. E. A quantitative chemical and physiological study of nutrient solution for plant cultures. *In* Physiological Researches, vol. 1, no. 4, p. 133–245. 1914.

[8] Shive, J. W. A study of physiological balance in nutrient media. *In* Physiological Researches, vol. 1, no. 7, p. 327–397. 1915.

triangular system with good effect. Both of these workers omitted the outside lines of the triangle, confining themselves to the more complete mixtures represented by the interior of our triangle system. Both investigators made up their solutions on the basis of osmotic pressure instead of percentages. The salts used by Tottingham were $Ca(NO_3)_2$, $KNO_3$, $KH_2PO_4$, $MgSO_4$, while Shive omitted the $KNO_3$ as contributing no ions not supplied by the other salts. More recently Wolkoff[9] at Rutgers College, in continuing the work of Shive, substituted $(NH_4)_2SO_4$ for the $KNO_3$ in Tottingham's solution, using the triangle for study and interpretation. For the results obtained by these workers the originals must be consulted.

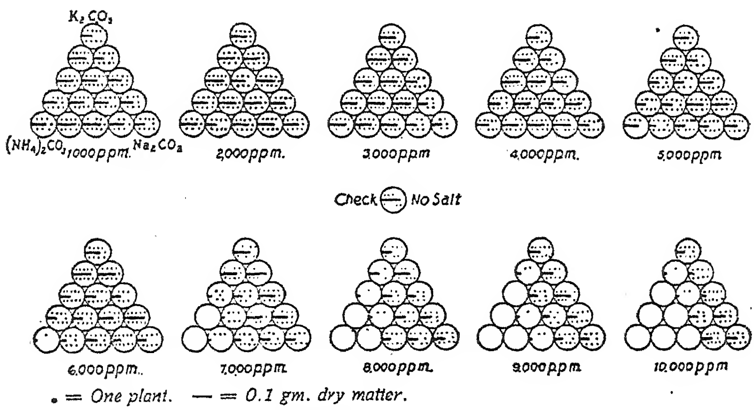


FIG. 37. Method of representing results as used by Harris. Diagram showing the number of wheat plants up and dry matter produced in 24 days on Greenville loam with ammonium carbonate, sodium carbonate, and potassium carbonate in different combinations and concentrations.

McCall[10] has also used our triangle system with interesting results in his work on the physiological balance of nutrient solutions. The salts used were calcium nitrate, magnesium sulfate, and potassium acid phosphate. The composition of his solutions used in sand cultures are represented by the diagram reproduced in figure 38. The variations are in 10-percent stages, but McCall, like Tottingham and Shive, omits the outside lines which comprise the constituents alone and the combinations of two, confining himself to a consideration of the variously constituted mixtures of the three components.

[9] Wolkoff, M. I. Effect of ammonium sulphate in nutrient solution on the growth of soybeans in sand cultures. *In* Soil Science, 5: 123–150. 1918.

[10] McCall, A. G. The physiological balance of nutrient solutions for plants in sand cultures. *In* Soil Science, 2: 207–253. 1916.

True and Bartlett,[11] in their study of the exchange of ions by plants growing in solution cultures, used this system. The salts used were the nitrates of potassium, calcium, and magnesium. The composition is stated in terms of concentration as to normality instead of on a percentage basis. The plan is reproduced in figure 39. Each point

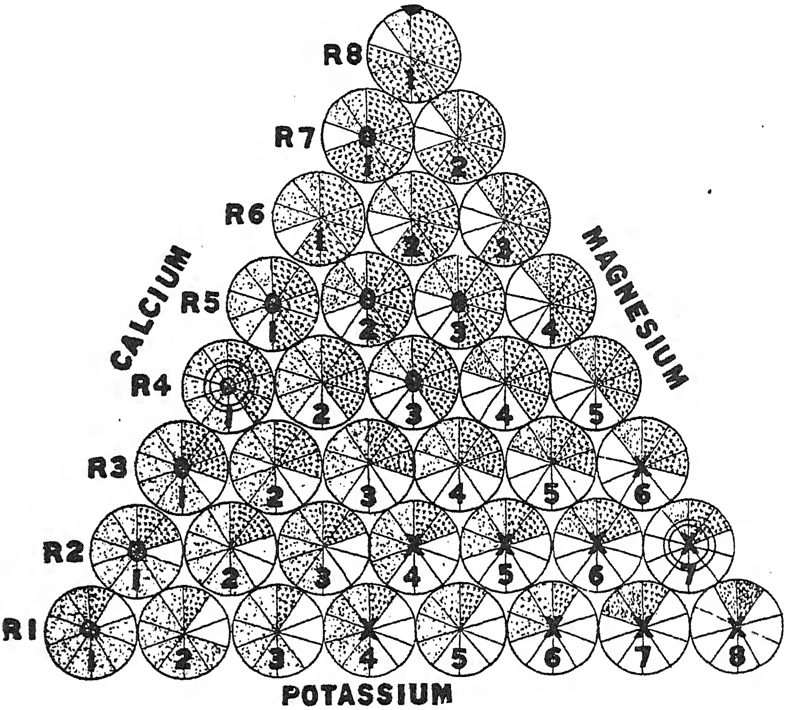


FIG. 38. Triangular diagram used by McCall, showing the arrangement of the sand cultures with respect to the partial concentrations of the three salts employed. Unshaded segments represent the proportions of $Ca(NO_3)_2$: stippled segments the $MgSO_4$: and the segments shaded with crosses the $KH_2PO_4$. The best nine cultures are marked X, while the poorest are marked O.

in the figure represents a solution, the original composition of which is indicated on the three intersecting lines reading upward from the intersection. The sum of the numerals at the intersection at any point is 140, indicating a total concentration of $140N \times 10^{-6}$. The figures given at the intersections for the residual concentration at the time

[11] True, R. H., and Bartlett, H. H. The exchange of ions between the roots of *Lupinus albus* and culture solutions containing three nutrient salts. *In* Amer. Jour. Botany, 3: 47–57. 1916.

of maximum absorption are based on the original concentration, in each case, $140N \times 10^{-6}$ being considered as 1.000.

True[12] also used the triangle system in his study of the effects of calcium in its relation to plant nutrition.

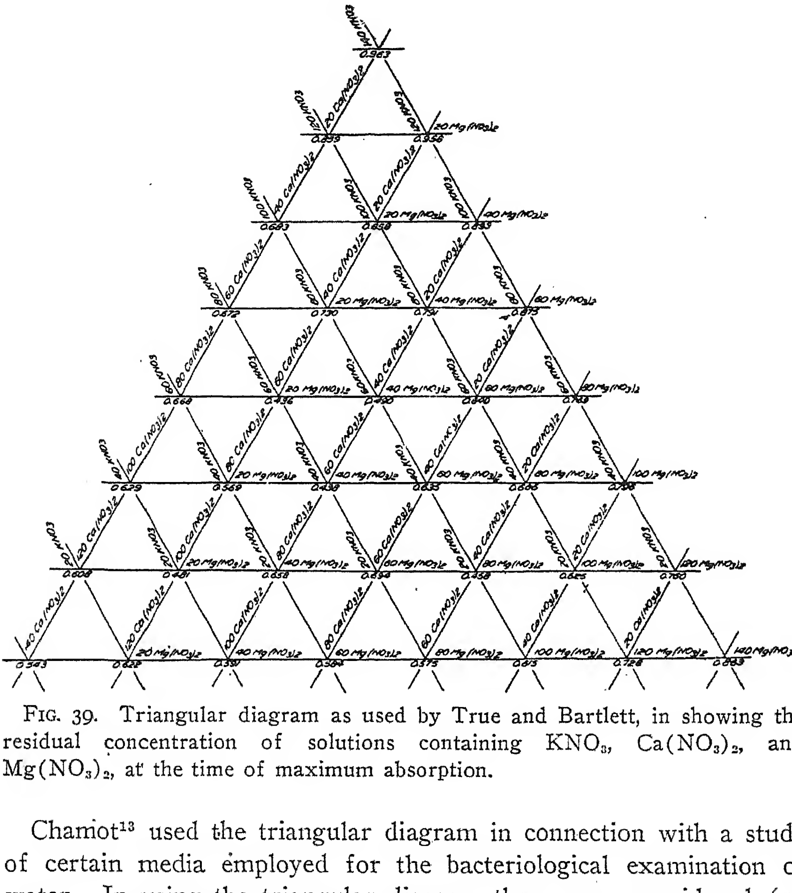

FIG. 39. Triangular diagram as used by True and Bartlett, in showing the residual concentration of solutions containing $KNO_3$, $Ca(NO_3)_2$, and $Mg(NO_3)_2$, at the time of maximum absorption.

Chamot[13] used the triangular diagram in connection with a study of certain media employed for the bacteriological examination of water. In using the triangular diagram there were considered (1) the concentration of peptone, (2) the concentration of the inorganic salts present, and (3) the nature of the reaction of the medium. He

[12] True, R. H. Calcium in its relation to plant nutrition. Presented before the American Society of Agronomy at its Washington meeting, 1917. Unpublished.

[13] Chamot, E. M., and Redfield, A. W. I. The Schardinger-Dunham medium for testing for the presence of hydrogen sulphide forming bacteria. *In* Jour. Amer. Chem. Soc., 37: 1606–1630. 1915.

Chamot, E. M., and Sherwood, C. M. II. Lactose-peptone media. *In* Jour. Chem. Soc., 37: 1949–1959. 1915.

also applied it to mixtures of four components, i. e., in addition to those noted above he used carbohydrates, but in this case he followed the procedure already mentioned in connection with the use of toxic organic substances earlier in this paper, viz., by keeping this fourth component constant in all the cultures of the triangle.

### The Triangular System in Field Experiments.

Following the use of the triangle system in our solution culture work, the same system was used in field studies on the action of fertilizers. The system was first laid out on the Arlington Farm in 1909, and at the Pennsylvania Agricultural Experiment Station Farm

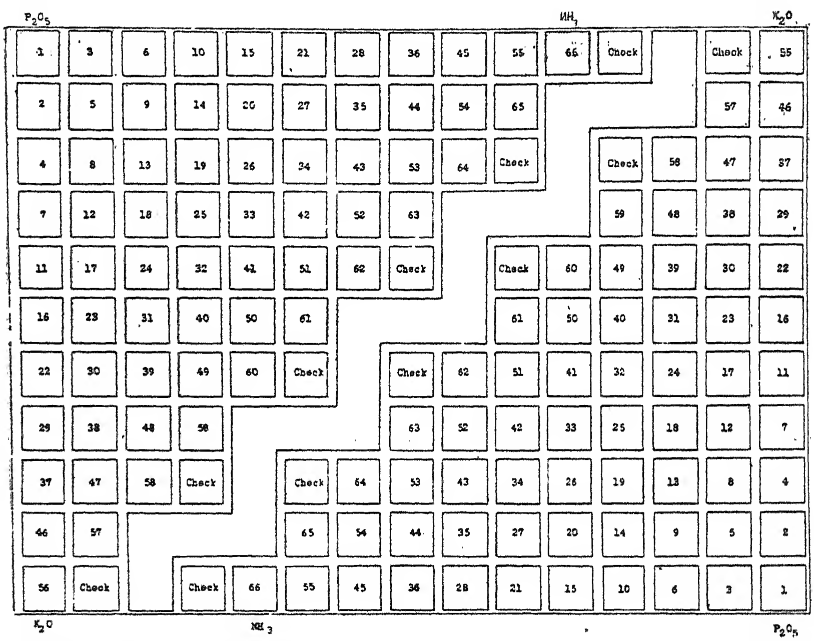

Fig. 40. Plat showing the field arrangement of two triangle systems in small rectangular plats.

in 1910. The plats used are small and therefore arranged in the form of the triangle, although this is by no means a requisite of the system. The checks run across the field diagonally at intervals and a strip of original untreated soil is maintained in sod between the triangles.

At the Pennsylvania Agricultural Experiment Station Farm the fertilizer test is made on grass land. When the experiment was

begun in 1910, the area on which the plats were located had a fairly uniform stand of grass consisting almost entirely of Canada bluegrass, Kentucky bluegrass, and timothy, with a very little white and red clover. It was estimated that Canada bluegrass covered about 50 percent of the area, Kentucky bluegrass about 30 percent, and timothy about 20 percent.

The soil is of the Hagerstown series. The surface soil varies in depth from 7 to 11 inches, and mechanical analyses of the soil and subsoil of plats taken at regular intervals show that the surface soil is silt loam and silty clay loam and the subsoil, clay and silty clay loam.

The plats were laid off according to the triangular system as shown in figure 40. They are 10 feet square and are separated by 2-foot paths. The plats were laid off in duplicate with a 10-foot space separating the two series, or triangles. Besides the 66 treated plats, there are 6 check plats in each series. The unused dividing strip and the 2-foot paths are kept in grass which is cut when the grass on the plats is cut. Here one may study the untreated soil.

As laid out, the two series form a rectangle, and all outside corners of the plats on the boundaries are marked with posts $4 \times 4$ inches which extend out of the ground 12 inches. These are outside of the plat so that the inside corner of the post coincides with the outside corner of the plat. For any desired purpose the boundaries of the plats are defined by stretching twine both ways across the two triangles.

The fertilizers have been applied in early April of each year just after the grass began to grow. The fertilizers are weighed out into wide-mouth bottles as previously described. After marking off the plats, the content of each bottle is mixed with about a quart of dry sand and then distributed by hand as evenly as possible. The fertilizer which each plat receives is at the rate of 50 pounds per acre of the active fertilizer constituents.

Some of the results obtained in this grass experiment have been presented in an earlier report,[14] but there are further interesting changes in the composition of the grasses which will form the subject of a later report. These changes in grass composition appear to result from the different fertilizer ratios and we wish here to call particular attention to the use of the triangle system and diagram in

[14] Noll, C. F., Schreiner, Oswald, and Skinner, J. J. Fertilizer ratio experiments with grass on Hagerstown loam. *In* Ann. Rept. Pa. State Coll. for the year 1913–1914, pt. 2, p. 22–36. 1915.

bringing out these facts. Each plat was analyzed botanically and the proportion of Kentucky bluegrass, Canada bluegrass, timothy, red clover, and white clover present stated on a percentage basis. This means 330 figures for each triangle and these are very easily handled by representing each plat or point in the triangle by a circle and letting each grass percentage represent a segment of the circle, much like the diagram of Plate 5, using 3 different shades of green for the three grasses and two shades of red for the clovers. When this is done it becomes strikingly apparent that the clovers are decidedly more prominent in that area of the triangle which is low in nitrogen. Originally Canada bluegrass was predominant. In the higher nitrogen area, Kentucky bluegrass is now predominant and the Canada bluegrass appears to be gradually crowded out. These facts could not have been easily seen or portrayed without the use of the triangular system of experimentation and the use of the diagram in the interpretation of the results.

At the Arlington Farm the manner of laying out the plats and the size are the same as the grass plats just described, but there are four triangles in the experiment. One of these is devoted to the growing of wheat, year after year, while the other three are devoted to a rotation of wheat, corn, and cowpeas, each crop being grown on one of the triangles. Plate 6 shows two general views of the field devoted to this work. Plate 6, figure 1, shows the preparation of the ground for planting after the fertilizers have been applied, the stakes marking the individual plats, while figure 2 shows the harvested crop from the plats.

A similar plan of experimentation was devised for orchard or grove fertilizer tests. Blocks of four or nine trees are selected as a unit for each treatment and careful notes made of their condition. In the case of an orange grove 1 pound of the fertilizer constituents was applied per tree.

In 1917 the Maine Agricultural Experiment Station at Aroostook Farm, near Presque Isle, Maine, inaugurated a fertilizer experiment, using our triangle system and employing 20 percent differences in the fertilizer combinations, as shown in figure 29. The fertilizer carriers in the regular 21 combinations were the phosphate as acid phosphate, the potash as potassium sulfate, and the nitrogen as one-third sodium nitrate and two-thirds ammonium sulfate. In addition a certain mixture was chosen and changes made to include other carriers, as follows: (*a*) For the acid phosphate an equivalent amount of floats is substituted, and (*b*) for the inorganic nitrogen an equivalent amount

FIG. 1. General view of the triangle fertilizer experiments on the Arlington Farm, Virginia. Preparation of the soil.

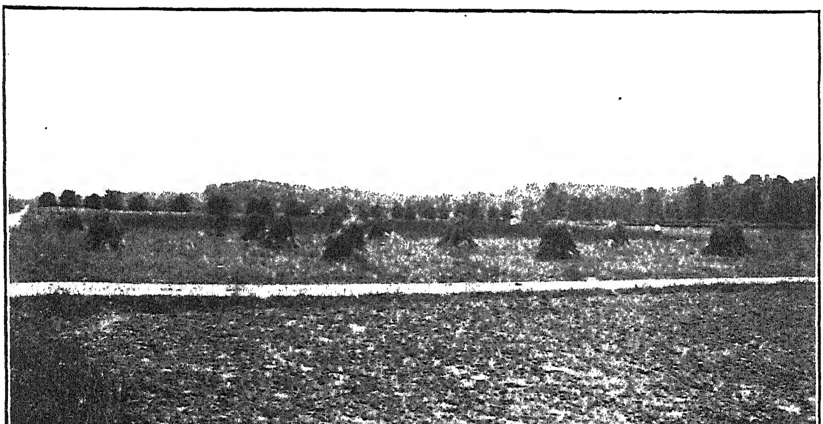

FIG. 2. General view of the triangle fertilizer experiments on the Arlington Farm, Virginia. Harvesting the wheat.

FIG. 1. General view of triangle fertilizer experiments on potatoes at Presque Isle, Maine. The treatments were arranged in double rows.

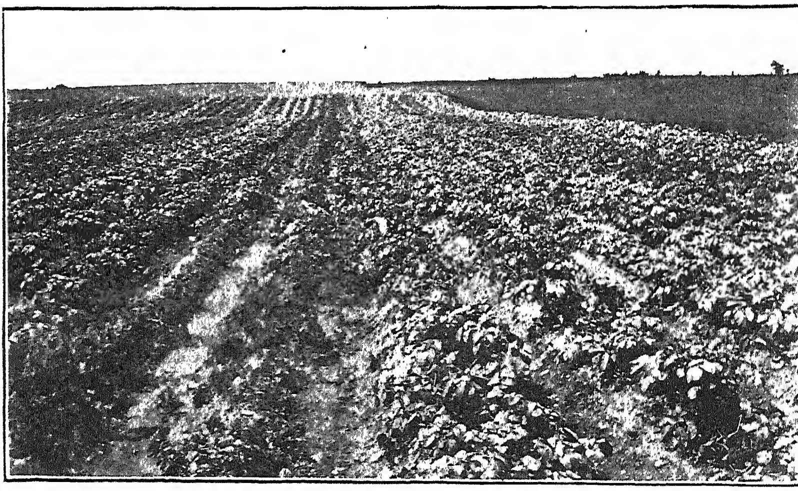

FIG. 2. View of triangle fertilizer experiments on potatoes at Presque Isle, Maine. Note the plants dying in the two rows on the left, one of the treatments without potash. Note also the series of darker rows in pairs occurring at intervals. These are the other no-potash treatments.

of organic nitrogen is substituted, both as dried blood and as high-grade tankage. The crops grown are potatoes, oats, and clover in rotation, each crop being grown each year on one of the series of plats. The plats are one-fortieth acre in area. The total quantity of active fertilizer constituents, $P_2O_5$, $NH_3$, and $K_2O$ applied per acre is 240 pounds to potatoes, 80 pounds to oats, and 40 pounds to clover The general scheme of the field arrangement of the plats is shown in figure 41.

A further study in which the triangle system was used was in connection with the potash hunger of the potato. In this experiment the 21 treatments were in two rows each of such length as to make one-

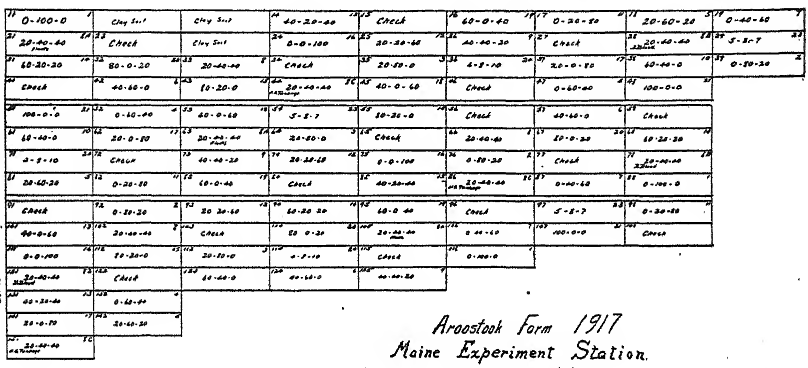


FIG. 41. Plat of the triangle fertilizer experiment at Aroostook Farm of the Maine Agricultural Experiment Station. Plats not arranged in triangle form.

twentieth of an acre for each treatment. Every three treatments or six rows were separated by the insertion of two check rows. The experiment was laid out in a field of which a carefully surveyed and detailed soil map had been prepared. Two soil types with gradations of each were involved and the crop was in each case on both soil types. Each soil type was harvested separately for each treatment. The details of this work and the highly interesting and different results obtained for the two soil types will be reported upon later.[15]

Plate 7, figure 1, shows this field triangle experiment at blooming time. The characteristic symptoms of potash hunger are a deeper green foliage of the plants than is normal, with a crinkled appearance of the leaf, which curves downward. This darker green gives way later to a distinct bronzing of the leaves, which finally die and the

[15] This was a cooperative study of potash hunger of the potato with special reference to soil type differences, carried on by the Bureau of Plant Industry and the Maine Agricultural Experiment Station.

plant collapses completely. Plate 7, figure 2, shows some of the collapsed plants on one of the no-potash plats of the triangle (No. 6) in the foreground. Attention is called to the series of darker lines of two-row treatments which can be distinctly seen even in the photograph and in the field these were very striking indeed. These are the no-potash plats of the triangle with the darker green or bronze-colored foliage characteristic of this trouble. This triangle experiment brought out strikingly the effect which potash in the fertilizers has in controlling this war-time disease, and shows how it is practical to use such a system in farm experimentation for solving fertilizer needs for any particular soil or crop.

## RELATIVE EFFECT OF SODIUM CHLORIDE ON THE DEVELOPMENT OF CERTAIN LEGUMES.[1]

G. W. HENDRY.

### INTRODUCTION.

The experiment here reported was initiated to observe the relative reaction to NaCl of certain leguminous crops cultivated extensively in California. Because of the complexity of the problem no effort has been made to arrive at the absolute tolerance of any variety and even the relative tolerance, indicated under the conditions of this experiment, may not be maintained under changed conditions or with other salts or combinations of salts.

Thirteen selected varieties were grown in the greenhouse in 1-quart glass jars filled with chemically pure quartz sand, to which alkali in the form of NaCl was added in five different concentrations, viz., 2,000, 8,000, 15,000, 25,000, and 50,000 parts per million of solution, equivalent to 0.04 percent, 0.16 percent, 0.3 percent, 0.5 percent, and 1.0 percent respectively of alkali based on the dry weight of the sand. In addition each jar was supplied from time to time with plant food in the form of a standard nutrient solution. Each variety was also grown in a culture receiving no NaCl. Sprouted seeds of all varieties were placed in the sand on September 10, but the seeds were placed in the germinator in preparation for the experiment as follows: Windsor bean and garbanzo, September 3; Cranberry, Red Kidney, Bayo,

[1] Contribution from the Division of Agronomy, College of Agriculture, University of California, Berkeley, Cal. Received for publication April 14, 1918.

and lima beans, September 4; Pink, Red Mexican, Lady Washington, Small White, and Blue Pod beans, September 5; and Blackeye cowpea and Tepary bean, September 6. By this progressive arrangement the radicles of all varieties were about 1 inch in length when planted September 10.

### Relative Effects of NaCl Concentration on Plant Development.

In Table 1, the varieties are grouped in the order of their apparent resistance to NaCl, and observations are recorded on the comparative effect of alkali concentration on the duration of life, height growth, and total leaf area.

Table 1.—*Relative effects of NaCl concentration on life period, height growth, and leaf-area of certain leguminous crops.*[a]

| Class and variety. | No. of days plants lived. | | | | Height in inches when 32 days old. | | | | Relative leaf surface,[b] percent. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Check. | NaCl 0.04 per-cent. | NaCl 0.16 per-cent. | NaCl 0.3 per-cent. | Check. | NaCl 0.04 per-cent. | NaCl 0.16 per-cent. | NaCl 0.3 per-cent. | Check. | NaCl 0.04 per-cent. | NaCl 0.16 per-cent. | NaCl 0.3 per-cent. |
| *Most tolerant:* | | | | | | | | | | | | |
| Blackeye cowpea | [c]90 | [c]90 | [c]90 | [c]90 | 14.0 | 14.0 | 6.5 | 4.5 | 100 | 94.0 | 16.7 | 8.0 |
| Windsor bean | [c]90 | [c]90 | [c]90 | 67 | 32.0 | 22.0 | 19.0 | 9.0 | 100 | 60.0 | 30.7 | 9.3 |
| Mexican garbanzo | [c]90 | [c]90 | 66 | 59 | 23.0 | 25.0 | 16.0 | 11.0 | 100 | 76.4 | 50.0 | 15.0 |
| *Moderately tolerant:* | | | | | | | | | | | | |
| Lewis lima | [c]90 | [c]90 | [c]90 | 50 | 54.0 | 27.0 | 10.0 | 6.5 | 100 | 51.0 | 20.0 | 3.1 |
| White tepary | [d]90 | [d]90 | [d]90 | 44 | 52.0 | 42.0 | 32.0 | 6.7 | 100 | 75.2 | 27.5 | 6.0 |
| *Least tolerant:* | | | | | | | | | | | | |
| Cranberry | [d]85 | [d]85 | .... | 40 | 42.0 | 32.0 | .... | 6.0 | 100 | 51.9 | .... | |
| Small white | [d]90 | [d]90 | [d]90 | 31 | 52.0 | 32.0 | 7.0 | | 100 | 98.0 | 29.5 | |
| Red kidney | [d]90 | [d]90 | 71 | 31 | 19.0 | 20.0 | 10.5 | | 100 | 40.5 | 12.7 | |
| Lady Washington | [d]86 | [d]86 | 56 | 31 | 27.0 | 11.0 | 6.5 | | 100 | 61.1 | 14.7 | |
| Pink | [d]76 | [d]81 | 50 | 31 | 11.0 | 9.5 | 7.0 | | 100 | 40.0 | 8.4 | |
| Red Mexican | [d]86 | [d]86 | 50 | 31 | 10.0 | 9.5 | 5.0 | | 100 | 71.0 | 4.7 | |
| Bayo | [d]90 | .... | 61 | 15 | 29.0 | .... | 2.3 | | 100 | .... | 47.1 | |
| Blue pod | [d]90 | [d]90 | 46 | 10 | 48.0 | 36.0 | 6.0 | | 100 | 90.5 | 17.8 | |

[a] None of the plants grew in the 1.0 percent solution of NaCl. In the 0.5 percent solution only the Windsor bean and the Mexican garbanzo survived, both of them living for 45 days. The former reached a height of 1 inch and the latter of 4 inches, while the relative leaf surfaces were reduced to 3.6 and 2.0 percent of their respective checks.

[b] The relative leaf surface is expressed in terms of leaf coefficient or average number × average length × average width. Taken when plants were 46 days old.

[c] Still growing when experiment was stopped.

[d] Ripened seed.

The groupings employed in Table 1 are based principally upon the data contained therein, but were influenced somewhat, particularly in the arrangement of the varieties within the groups, by the more intangible qualities of general thrift and vigor. It is significant that each of the varieties in the first (most tolerant) group, Blackeye cowpea (*Vigna sinensis*), Windsor bean (*Vicia faba*), and Mexican garbanzo (*Cicer arietinum*), represents a different genus from any of the others; and that the varieties in the second group (moderately tolerant), Lewis lima (*Phaseolus lunatus*) and White tepary (*P. acutifolius* var. *latifolius* Freeman), both represent different species from those in the last group (least tolerant), all of which are varieties of *Phaseolus vulgaris*.

### Relative Effects of NaCl Concentration on Nodule Development.

Nodules of nitrogen-fixing bacteria developed naturally on all varieties excepting the lima, tepary, and garbanzo, and were most numerous and largest in each instance in the check culture, diminishing in number and size as the strength of the solution increased, and disappearing entirely in the soils containing NaCl equivalent to 0.3 percent and 0.5 percent on the dry basis. The fact that the nodules on the Windsor bean were apparently less injured by NaCl than those on the Blackeye cowpea suggests that the organisms themselves may possess specific alkali tolerance. Some observations bearing upon this relationship are given in Table 2.

TABLE 2.—*Relative effects of NaCl concentration on nodule development.*

| Variety. | Average number of nodules per plant. | | | | Average diameter of nodules in mm. | | | |
|---|---|---|---|---|---|---|---|---|
| | Check. | NaCl 0.04 percent. | NaCl 0.16 percent. | NaCl 0.3 percent. | Check. | NaCl 0.04 percent. | NaCl 0.16 percent. | NaCl 0.3 percent. |
| Windsor bean | 110 | 85 | 50 | 0 | 2.0 | 4.0 | 2.1 | ...... |
| Small white bean | 50 | 35 | 6 | 0 | 3.75 | 2.0 | 1.5 | ...... |
| Bayo bean | 40 | ...... | 15 | 0 | 5.5 | ...... | 3.0 | ...... |
| Blackeye cowpea | 16 | 0 | 0 | 0 | 3.8 | ...... | ...... | ...... |

### Relative Effects of NaCl Concentration on Blossoming Period.

The occurrence of the blossoming period was retarded by the presence of NaCl in the soil, and the period of retardation increased as the concentration of salt became greater. The retardation was more in some varieties than in others. The Pink bean, however, was an exception, blossoming simultaneously in all cultures, includ-

ing the check, independently of salt concentration. There was no apparent correlation between the period of retardation in blossoming and alkali resistance. Observations on the blossoming periods of six varieties are recorded in Table 3.

TABLE 3.—*Relative effects of NaCl concentration on blossoming periods of several legumes.*

| Variety. | Date of opening of the first blossoms. | | | Total period of retardation in 0.16 percent solution. |
|---|---|---|---|---|
| | Check. | NaCl 0.04 percent. | NaCl 0.16 percent. | |
| | | | | *Days.* |
| Windsor bean | Oct. 12 | Nov. 5 | Nov. 8 | 27 |
| White tepary | Oct. 20 | Oct. 22 | Oct. 26 | 6 |
| Red kidney | Oct. 12 | Oct. 30 | Nov. 3 | 22 |
| Pink | Oct. 8 | Oct. 8 | Oct. 8 | 0 |
| Lady Washington | Oct. 17 | Oct. 27 | Nov. 10 | 24 |
| Small white | Oct. 22 | Oct. 25 | Nov. 8 | 17 |

## SUMMARY.

The Windsor bean (*Vicia faba*), the Blackeye cowpea (*Vigna sinensis*), and the Mexican garbanzo (*Cicer arietinum*), were less affected by NaCl than the other varieties tested.

The Lewis lima (*Phaseolus lunatus*), and the White tepary (*P. acutifolius* var. *latifolius* Freeman), were less affected by NaCl than any of the varieties of *Phaseolus vulgaris* tested.

The visible effects of NaCl upon the development of the plants was as follows:

1. Retardation of germination;
2. Retardation of height growth;
3. Reduction of the number of leaves;
4. Reduction of the size of the leaves;
5. Retardation of the blossoming period;
6. Reduction in the number of nodules;
7. Reduction in the size of the nodules; and
8. Premature death.

# RELATION BETWEEN YIELD AND EAR CHARACTERS IN CORN.[1]

T. B. HUTCHESON and T. K. WOLFE.[2]

In recent years some doubt has arisen as to the value of certain score-card points as a criterion for selecting high-yielding strains of corn. The question is, do the points emphasized on the score card have any relation to the yielding capacity of the individuals possessing these characters? It would be of great importance to determine which of these points are and which are not indicative of high yield, if any relation at all exists. Considerable work has been done along this line, some of which will be reviewed briefly in this paper.

The usual method in studying the relation of ear characters to yield has been to select ears with the characters desired and then obtain the yield from these selected ears when planted. In this method of procedure, there is likely to be some variation in the yield of different ears, due to cross-pollination. It is well known that the effect of broad breeding in corn is often marked. It may be that this effect has overshadowed differences in yield due to different characters possessed by the selected ears.

The data in this paper deal with the relation between yield and ear characters of the progeny of certain seed ears selected at random. The characters studied in relation to yield are average length, average circumference, ratio of tip to butt circumference, average circumference of cob, percentage of grain, average number of rows, average length of kernels, uniformity of exhibit, shape of ears and trueness to type, character of tips, character of butts, uniformity of kernels, space between kernels, and space between rows.

## REVIEW OF LITERATURE.

In extensive experiments conducted at the Ohio (10)[3] station it was found that there was no material relationship between various seed ear characters and yield.

[1] Paper No. 4, Department of Agronomy, Virginia Agricultural Experiment Station, Blacksburg, Va. Received for publication April 28, 1918.

[2] The writers wish to acknowledge the valuable assistance of Mr. S. C. Harman in obtaining the measurements reported in this paper.

[3] Numbers in parentheses refer to "Literature cited," p. 255.

Love (4) obtained a slight increase in yield from planting long ears and from planting heavy ears. However, such seed ear characters as number of rows, average weight of kernel, and ratio of tip to butt did not have any marked effect on yield.

Love and Wentz (5) studied the relation of such seed ear characters as length, average circumference, average cob circumference, weight of ear, number of rows, average weight, average length, average width of kernels, and percentage of grain to yield. The average circumference of the seed ear was the only character which showed any significant relation to yield. The writers conclude that "the only basis left for selecting high-yielding seed corn is the ear-to-row progeny test."

Hartley (2), studying four varieties of corn over a period of six years, in which more than 1,000 ear-to-row tests of production were made, obtained results indicating that no visible characters of apparently good seed ears are indicative of high yielding capacity.

Pearl and Surface (8), in a two years' ear-to-row test, found that there was no evidence of any close association or correlation between the size and conformation of the seed ear and the yield of corn obtained from it on planting.

McCall and Wheeler's (6) experiments indicate that neither length, weight, nor density of ear is correlated with yield.

Sconce (9), in studying the relation between various seed ear characters to yield in the Reid Yellow Dent and Johnson County White varieties, found that ears containing 18 or 20 rows gave the highest yield. In Reid Yellow Dent, small-germ kernels gave the best results, but the large-germ kernels of Johnson County White gave the highest yield. The relation of shape of kernel and yield is striking in both varieties used. The writer states: "The kernel of ideal shape, which tapers slightly and has the square shoulders and full tip, has been giving the best results. Not once since beginning the experiment has an ill-shaped kernel on the average outyielded the ideally shaped kernel."

Montgomery (7) found that the long, smooth type of seed ears outyielded the standard type ears. Also, extra large ears are no more valuable than medium-sized ears for seed purposes.

In an experiment conducted at the Iowa station (3) 500 ears of corn were secured from the field without any selection and scored by twenty-five judges. A portion of each ear was planted in the field; the first year's results indicate that the ears receiving the highest scores were also the most productive in the field. As compared with

the bulk of the ears, the fifty best ears, as selected by the majority of the judges, yielded on the average 5 bushels more to the acre.

Experiments conducted by Cunningham (1) indicate that the length of ear has little relation to yield, but that varieties differ in this respect. The indications are that slender seed ears are more productive than those of comparatively large circumference. There was apparently no relation between the character of tips and butts and percentage of grain to cob to yield. It was found that ears of intermediate indentation outyielded smooth or rough ears, while the rough consistently yielded lower than the smooth ears. The relation of number of rows to yield varied with different varieties.

## Material and Methods.

The corn used in this work was Boone County White, which has been grown at the experiment station for nine years and selected for earliness. By selection a strain has been developed adapted to the mountain sections of the State. This strain matures about ten days to two weeks earlier than other strains of this variety which have not been selected for earlines.

All measurements were taken in inches and the yield expressed in bushels per acre. In 1916, 140 ears were planted in the ear-to-row test; in 1917, 98 ears were planted. These ears were selected at random and two rows 66 feet long were planted from each ear, the two rows constituting one one-hundredth of an acre. At husking time the grain from the two rows produced by each ear was combined and later shelled and the yield per acre computed. Each year, before shelling, a certain number of high-yielding and low-yielding strains were selected and the data secured which are presented in this paper. The average circumferences of the ear and of the cob were obtained by averaging the butt and tip circumferences. The ratio of tip circumference to butt circumference was obtained by dividing the former by the latter. In this way the shape of the ear was determined. The nearer this ratio approaches unity the more cylindrical is the ear. The percentage of grain was calculated by dividing the weight of shelled corn by the weight of grain and cob. The number of rows was determined by counting the rows on ten ears of each strain selected. The average length of kernels was found by subtracting the average circumference of the cob from the average circumference of the ear. The length of the kernels was then calculated by the formula, circumference $= 2\pi r$ ($r =$ radius or length of kernel). Each strain selected was scored by use of the corn score card adopted by the

station and corn growers of this State. Data were secured by use of the score card on the following characters: Uniformity of exhibit, shape of ears and trueness to type, character of tips, character of butts, uniformity of kernels, shape of kernels and size of germs, space between rows, and space between kernels. The value of these latter characters is expressed in percentages, 100 percent being a perfect score.

## Results.

In Table 1 data are presented showing the relation between yield and various ear characters of the progeny of a number of ears of Boone County White corn planted in the ear-to-row test.

Table 1.—*Relation between yield and various ear characters of the progeny of different ears of Boone County White corn at the Virginia station in 1916 and 1917.*

| Character. | High yielding strains. | | Low yielding strains. | | Average. | |
|---|---|---|---|---|---|---|
| | 1916. | 1917. | 1916. | 1917. | High yielders. | Low yielders. |
| Average length, in. | 8.61 | 8.31 | 8.30 | 7.65 | 8.46 | 7.98 |
| Average circumference, in. | 6.90 | 6.70 | 6.69 | 6.46 | 6.80 | 6.57 |
| Ratio of tip to butt circumference | .85 | .88 | .84 | .87 | .86 | .86 |
| Average circumference of cob, in. | 4.09 | 4.29 | 3.97 | 4.08 | 4.19 | 4.03 |
| Yield, bushels per acre | 82.74 | 62.30 | 61.97 | 47.58 | 72.52 | 54.78 |
| Percentage of grain | 85.27 | 79.46 | 83.97 | 80.57 | 82.37 | 82.27 |
| Average number of rows | 16.77 | 16.51 | 16.57 | 16.35 | 16.64 | 16.46 |
| Average length of kernels, in. | .45 | .38 | .43 | .38 | .42 | .41 |
| Uniformity of exhibit, percent | 55.00 | 49.44 | 48.00 | 48.18 | 52.22 | 48.09 |
| Shape of ear and trueness of type, percent | 55.42 | 41.67 | 50.50 | 38.64 | 48.55 | 44.57 |
| Character of tips, percent | 60.83 | 26.11 | 47.00 | 25.50 | 43.47 | 36.25 |
| Character of butts, percent | 59.17 | 39.44 | 55.00 | 40.91 | 49.31 | 47.96 |
| Uniformity of kernels, percent | 55.83 | 43.89 | 56.00 | 35.45 | 49.86 | 45.73 |
| Shape of kernels and size of germ, percent | 64.58 | 40.56 | 53.50 | 40.45 | 52.57 | 46.98 |
| Space between kernels, percent | 71.25 | 53.33 | 71.50 | 52.27 | 62.29 | 61.89 |
| Space between rows, percent. | 69.58 | 45.56 | 65.00 | 52.73 | 57.57 | 58.87 |

In 1916 twelve high-yielding and ten low-yielding strains were selected. The high-yielding strains contained 756 ears which were measured for length and 716 ears measured for circumference. The low-yielding strain contained 439 ears which were measured for length and 418 measured for circumference.

In 1917 nine high-yielding and eleven low-yielding strains were

selected. In the high-yielding strains 514 ears were measured for length and 500 ears for circumference. In the low-yielding strains 540 ears were measured for length and 534 for circumference.

A study of Table 1 shows that in 1916 the high-yielding strains produced 20.77 bushels more per acre than the low-yielding strains. Also, the data obtained in that year are in favor of the high-yielding strains in every case save two, uniformity of kernels and space between kernels. In these two instances, the differences are slight, 0.17 percent, and 0.25 percent respectively. In 1917, the difference in yield is 14.72 bushels. In this year the results are in favor of the high yielding strains in all instances save three, namely, percentage of grain, character of butts, and space between rows. The differences in these three instances are 1.11 percent, 1.47 percent and 7.17 percent, respectively. If the averages for the two years are considered, we find that the results are in favor of the high-yielding strains in every instance, except in the case of the space between rows. The difference here is 1.30 percent in favor of the low-yielding strains.

The negative relation between yield and space between rows is not surprising when the origin of the strain of corn is considered. As stated before, the strain has been developed especially for early maturity and in so doing a type has been secured with a rather greater distance between the rows than in the original variety.

The results for the two years are in close accord and are very suggestive. The data indicate that the points emphasized in the corn score card may be of value in selecting high-yielding strains. In other words, according to our results, high-yielding strains are high-scoring strains.

These results are more interesting when the prize-winning varieties of corn in Virginia are considered. For many years the standard varieties of corn in the State, based on yield and other desirable characteristics, have been Boone County White, Johnson County White, Collier Excelsior, Reid Yellow Dent, and Gold Standard. These varieties are not only the high-yielding varieties of the State, but are the ones which have taken the greater part of the prizes annually at the State fairs and at the fairs held by the State Corn Growers' Association, where the score card is used as a basis for awards.

## Conclusions.

The data reported in this paper indicate that:

1. The relation between yield and length, average circumference,

average circumference of cob, uniformity of exhibit, shape of ears and trueness to type, character of tips, uniformity of kernels, and shape of kernels and size of germ is significant.

2. The relation between yield and ratio of butt to tip circumference, percentage of grain, number of rows, average length of kernels, character of butts, space between kernels, and space between rows is small.

3. The points emphasized on the score card are of value in selecting high-yielding strains of corn.

4. High-yielding strains of corn are high-scoring strains.

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# INFLUENCE OF CEROTOMA TRIFURCATA ON THE NITROGEN-GATHERING FUNCTIONS OF THE COWPEA.[1]

LEWIS T. LEONARD and C. F. TURNER.

## INTRODUCTION.

The nodules of leguminous plants are recognized as fundamental sources of nitrogen for plant growth and any agency which tends to impede their normal formation or interfere with their nitrogen-fixing functions is worthy of scientific consideration. For a long time it has been known that the physical, chemical, and bacteriological forces of the soil influence the production of nodules, but recently McConnell[2] called attention to the destruction of the nodules of various legumes by the larvæ of the bean-leaf beetle, *Cerotoma trifurcata* Forst. McConnell has also reported[3] the destruction of nodules of wild legumes by the larvæ of *Eudiagogus rosenschoeldi* Fahrs in Mississippi and Arkansas. The first-mentioned beetle in its adult form is very destructive to the leaves of the legumes which it will attack, but this injury is quite noticeable, whereas the injury done by the larvæ to the roots and tubercles represents a type which is not evidenced by any superficial symptoms which the ordinary observer might consider (Plate 8, fig. 1). The cowpea and the garden bean are reported to be the principal plants which are subject to the ravages of these insects. As the cowpea is one of the most important legume crops in the sections where the beetles are apparently most destructive it was chosen for use in these experiments to determine the factors governing this type of injury.

It was at first thought that results could be obtained by conducting experiments in the vicinity of Washington D. C., and in 1914 field and can experiments were carried on at the Arlington Farm, Rosslyn, Va., but the results were vitiated by a cold, rainy season. Similar experiments of a more comprehensive character were conducted in

[1] Contribution from the Bureaus of Plant Industry and Entomology, U. S. Department of Agriculture, Washington, D. C. Received for publication April 5, 1918.

[2] McConnell, W. R. A unique type of insect injury. *In* Jour. Econ. Ent., 8: 261–267. 1915.

[3] McConnell, W. R. Another nodule destroying beetle. *In* Jour. Econ. Ent., 8: 551. 1915.

1915 at the same place, but the results did not justify their continuation. It was evident that climatic conditions obtaining in the latitude of Washington were not conducive to the normal life of the insect, regardless of the fact that Cerotoma bettles have been collected in this vicinity and as far north as New Jersey. The beetles used in these initial trials were collected in Mississippi and the eggs were oviposited at the Bureau of Entomology Field Station, Hagerstown, Md. It is possible that the strains of larvæ and beetles developing under abnormal conditions lacked the virility to function properly in the northern climate.

As the results at Washington were inconclusive and entirely unsatisfactory, it was decided to continue the experiments in the vicinity of Greenwood, Miss., under the direct supervision of the Federal entomological substation there.

## Experimental Data.

These experiments were carried out during the summer of 1916. Similar plots were arranged at Greenwood, Miss., on the rich black delta soil and at Grenada, Miss., on the poorer reddish hill soil. The location of these plots was determined on the basis of soil uniformity, contour of land, and proximity to fields planted or to be planted in cowpeas. These plots were cleared of all debris considerably before planting time so as to make the hibernating insects seek other quarters or die from exposure. Each plot was plowed and subdivided into smaller plots 4 feet square centered in 12-foot squares, thereby leaving a clear space 4 feet in width around each small plot. Before breaking ground the Greenwood plot was in grass and weeds while the one at Grenada was in clover.

Cages to protect the small plots from outside infestation and to restrict the travel of beetles introduced or developed in the cages were made from ¾-inch lumber and 18-mesh wire screen. The outside dimensions of the cages were 4 feet by 4 feet by 2½ feet. They were strongly built and well braced.

These cages were arranged in the order shown below.

Final Arrangement of Experimental Plots at Greenwood, Miss.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1<br>A | 2<br>B | 3<br>C | 4<br>O | 5<br>A | 6<br>B | 7<br>C |
| 14<br>A | 13<br>C | 12<br>A | 11<br>O | 10<br>A | 9<br>C | 8<br>A |
| 15<br>C | 16<br>A | 17<br>B | 18<br>O | 19<br>C | 20<br>A | 21<br>B |

Final Arrangement of Experiment Plots at Grenada, Miss.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | C | B | O | A | B | C |
| 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| A | C | A | O | A | C | A |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| C | A | B | O | C | A | B |

The smaller plots were numbered for convenience in handling samples.

Plots marked A were entirely inclosed in cages and twenty pairs of Cerotoma beetles were introduced into each except those in the center row bearing the numbers 8, 10, 12, and 14, into each of which forty Cerotoma eggs were inserted.

Plots marked B were covered with cages which were slightly elevated above the ground on one side to allow for normal infestation in conjunction with plants shaded by cages (Plate 8, fig. 2).

Plots marked C were inclosed the same as those marked A, but were not infested with beetles or eggs. These plots were devised to act as checks on the inclosed infested plots.

Plots marked O were not covered and served the purpose of open controls.

The cages from which it was intended to prevent outside infestation by beetles or larvæ were sunk 6 inches in the ground up to the top of the baseboard and precautions were taken to make them secure by filling all cracks and holes.

New Era cowpeas were planted in the small plots at Greenwood May 6, 1916, and at Grenada, May 25, 1916. Infestation was accomplished in accordance with the plans at Greenwood, June 14, 1916, and at Grenada, June 16, 1916. At the time of infestation the number of plants per plot was reduced to six. The crop was harvested at Greenwood, July 22, 1916, and at Grenada, August 2, 1916. The cowpea vines were cut about 3 inches from the ground. This forage was stored in cotton bags and dried in the sun. At the same time the crop was cut the roots were dug carefully and data taken on the total number of nodules per plot and the percentage of nodules injured by Cerotoma larvæ. The roots were also dried.

In the second series of experiments the plots at Greenwood were planted with Whippoorwill cowpeas August 7, 1916, and those at Grenada, August 9, 1916. Infestation in exactly the same quantities and manner as in the earlier experiments was introduced at Green-

FIG. 1. Cerotoma larvæ feeding on cowpea nodules and the character of the injury made. (Magnified 5 times.)

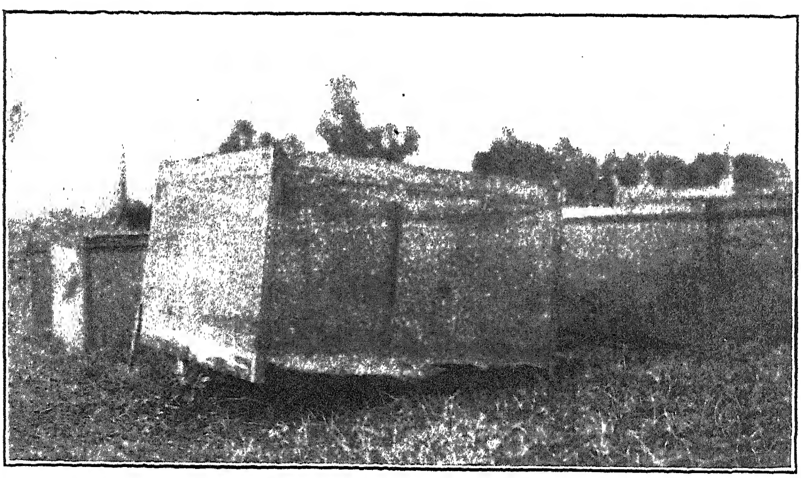

FIG. 2. Type of cage used and method of tilting to secure natural infestation.

wood, September 2, 1916, and at Grenada, September 5, 1916. As in the other experiments the number of plants were reduced to six.

These experiments were concluded at Greenwood October 17, 1916, and at Grenada October 18, 1916. Except for the collection of composite soil samples for nitrogen and bacteriological analyses the crop was treated the same as before and similar data obtained.

The material was dried in Mississippi and shipped to Washington, where it was carefully weighed and ground to a powder. The Bureau of Chemistry kindly made the nitrogen analyses recorded in Table 1.

TABLE 1.—*Summary of results obtained in experiments to determine Ceretoma injury to cowpeas in 1916.*

| Plot.[1] | Soil nitrogen, percent. | Soil-nitrifying bacteria per gram. | Ave. number of nodules per plot. | Percent of nodule injury. | Ave. total dry weight. | Percent of nitrogen. | | Total nitrogen, grams. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Tops. | Roots. | |
| NEW ERA COWPEAS AT GREENWOOD, MISS. | | | | | | | | |
| A (Introduced beetles) | 0.17 | 11,687,500 | 207.50 | 95.35 | 278.38 | 2.40 | 1.28 | 6.32 |
| B (Normal infestation) | 0.18 | 14,250,000 | 263.50 | 67.08 | 240.38 | 2.80 | 1.55 | 6.56 |
| C (Covered check) | 0.24 | 7,000,000 | 373.33 | 42.37 | 238.83 | 2.67 | 1.72 | 6.24 |
| A (Introduced eggs) | 0.38 | 5,750,000 | 284.50 | 59.63 | 197.38 | 2.75 | 1.72 | 5.26 |
| O (Open check) | 0.16 | 12,500,000 | 442.67 | 93.40 | 457.17 | 2.60 | 1.51 | 11.64 |
| NEW ERA COWPEAS AT GRENADA, MISS. | | | | | | | | |
| A (Introduced beetles) | 0.04 | 245,000 | 217.00 | 76.18 | 73.88 | 2.11 | 1.08 | 1.42 |
| B (Normal infestation) | 0.03 | 375,000 | 183.25 | 61.10 | 110.25 | 2.42 | 1.31 | 2.50 |
| C (Covered check) | 0.06 | 215,000 | 173.67 | 60.59 | 97.17 | 2.10 | 1.16 | 1.90 |
| A (Introduced eggs) | 0.03 | 232,500 | 177.50 | 65.53 | 93.13 | 2.47 | 1.26 | 2.16 |
| O (Open check) | 0.04 | 370,000 | 198.00 | 79.03 | 85.80 | 2.13 | 1.27 | 1.73 |
| WHIPPOORWILL COWPEAS AT GREENWOOD, MISS. | | | | | | | | |
| A (Introduced beetles) | 0.17 | 11,687,500 | 102.50 | 49.08 | 96.38 | 2.77 | 1.35 | 2.49 |
| B (Normal infestation) | 0.18 | 14,250,000 | 95.50 | 44.88 | 26.63 | 3.07 | 1.37 | .74 |
| C (Covered check) | 0.24 | 7,000,000 | 195.17 | 10.77 | 121.42 | 2.73 | 1.60 | 3.16 |
| A (Introduced eggs) | 0.38 | 5,750,000 | 122.75 | 21.12 | 114.50 | 2.91 | 1.51 | 3.14 |
| O (Open check) | 0.16 | 12,500,000 | 6.67 | 80.50 | 1.67 | | 0.51 | 0.01 |
| WHIPPOORWILL COWPEAS AT GRENADA, MISS. | | | | | | | | |
| A (Introduced beetles) | 0.04 | 245,000 | 137.75 | 46.10 | 22.00 | 2.71 | 1.14 | 0.52 |
| B (Normal infestation) | 0.03 | 375,000 | 110.75 | 20.25 | 11.38 | 3.11 | 1.46 | 0.30 |
| C (Covered check) | 0.06 | 215,000 | 150.67 | 10.02 | 21.63 | 2.78 | 1.23 | 0.54 |
| A (Introduced eggs) | 0.03 | 232,000 | 94.50 | 42.88 | 14.50 | 2.65 | 1.17 | 0.35 |
| O (Open check) | 0.04 | 370,000 | 29.67 | 73.00 | 3.67 | 0.69 | 0.46 | 0.02 |

[1] In the above summary data following A, B, C, A eggs, and O represent the average of 4, 4, 6, 4 and 3 plots respectively.

### Discussion of Results.

As will be noted in the summary of results, the second experiment, in which Whippoorwill cowpeas were used, is more striking than the first experiment, in which New Era cowpeas were used. This is probably due to factors such as planting time, climatic conditions, etc., rather than to the variety of cowpea.

The average of the dry weights of the New Era cowpeas from the open check plots at Greenwood is greater than the average weight of any of the other series of plots. It is evident that the plants in this particular set of open checks were well started and growing vigorously before the larvæ made an extensive attack on the roots. This factor coupled with climatic conditions and the natural richness of the soil will probably explain this apparently abnormal production of forage while the inclosed plots were somewhat hindered in their development by the unnatural conditions imposed upon them.

It is to be regretted that the inclosed check plots became infested in spite of the precautions taken. The presence of infestation in these cages may be explained on the ground that small female beetles crawled through the meshes of the screen or through the cracks at the corners of the cages made by the drying influence of the hot weather.

The results indicate that the nodule injury is related to the percentage of nitrogen in the roots. As the injury of the nodules increases the percentage of nitrogen in the roots decreases, or nitrogen lost is in proportion to the number of larvæ present. It should be noted that there was considerable damage done to the leaves of the cowpeas, much more in the second series of experiments than the first. The maximum damage to leaves apparently occurred in the B plots, although leaves were injured in practically every plot. The open check plots in the second series produced very spindly plants and the injury observed here was probably due almost entirely to the attacks of the larvæ on the roots.

The destructive character of the damage which may be done by these larvæ is shown rather forcibly in the experiments with Whippoorwill cowpeas; the plants did not develop much beyond the cotyledon stage.

Cowpea bacteria will fix atmospheric nitrogen in the nodules to the extent of approximately two thirds of the nitrogen obtained by the plant. Considering the Whippoorwill cowpea experiment at Greenwood we find that the bacteria took from the air an average of about 2.10 grams of nitrogen in the inclosed checks or C plots, and

in the open check plots an average of about 0.006 grams. A comparison of these two estimates will indicate an approximation of the damage it is possible for these insects and their larvæ to perpetrate. There is no doubt that the larvæ and beetles are high in nitrogen and to some extent excrete the nitrogen they consume in the soil surrounding the cowpeas on which they feed. Analyses of beetles indicated that in the air-dry state they contained 9.65 percent nitrogen, while air-dry larvæ contained 8.73 percent nitrogen. However, as it is possible for these insects during their life cycle practically to kill cowpea plants it will be readily seen that they constitute a direct or indirect menace to the nitrogen-gathering power of the cowpea.

The average total nitrogen fixed by the nodule bacteria in the Whippoorwill Greenwood-B plots or plots exposed at the bottom only is estimated to be about 0.50 gram, showing that the damage was limited to some extent by the covering. In the same series of plots it will be noticed that the A plots which were treated with beetles averaged a gain of amospheric nitrogen of about 1.86 grams, the artificially introduced beetles not doing as much damage as those which entered through normal infestation. The A plots which were treated with eggs took from the air about the same amount of nitrogen per plot as did the inclosed checks.

The dry weight column follows practically the same trend as the total nitrogen column and the percentage of nitrogen contained in the tops is fairly constant when the open checks in the second series are not considered.

## Conclusions.

1. Danger of extensive damage from Cerotoma beetles or their larvæ in the vicinity of Washington is slight.

2. Damage to the mutual nitrogen-fixing functions of the cowpea plant may be caused by these insect larvæ without superficial indication of such damage except the presence of the beetles and leaf injury.

3. Time of planting and preseason conditions are important factors in lessening the extent of damage. Planting should be done after the over-wintered beetles have laid their eggs; for the latitude of Greenwood, Miss., May 1 to 15 is the proper time. Rotation of crops, fall plowing, and clean culture will probably prove beneficial, but further work will demonstrate the efficacy of these methods.

4. Damage may range from practically nothing to the entire destruction of the plant.

5. The damage to the nitrogen content of cowpea roots is roughly proportional to the number of larvæ present.

# AGRONOMIC AFFAIRS.

## NOTICE OF ANNUAL MEETING.

The eleventh annual meeting of the American Society of Agronomy will be held in Baltimore, Md., on November 11 and 12, 1918; the hotel at which the meeting will be held will be announced later. Those who expect to present papers at this meeting are urged to send in titles promptly to the Secretary, Lyman Carrier, Department of Agriculture, Washington, D. C., so that the program can be planned and printed some weeks in advance of the meeting.

## MEMBERSHIP CHANGES.

The membership reported in the May issue of the JOURNAL was 649. Since that time 3 new members have been added, making the present membership 652. The names and addresses of the new members, with a correction of a name previously published and such changes of address as have been reported, follow.

### NEW MEMBERS.

ERDMAN, LEWIS W., Agr. Expt. Sta., College Park, Md.
HARLOW, H. C., Agr. College, Truro, N. S., Canada.
WILKINSON, J. V., 624 Egan St., Shreveport, La.

### CORRECTION OF ADDRESS.

RUEDA, BUENAVENTURA, Linea 97, Antiguo Entre 8 y 10, Vedado, Habana, Cuba.

### CHANGES OF ADDRESS.

ADAMS, E. L., Chico, Cal.
BELL, HENRY G., 1111 Temple Bldg., Toronto, Ont., Canada.
BREITHAUPT, L. R., R. R. No. 3, Payette, Idaho.
CHAPPELEAR, GEO. W., Normal Station, Harrisonburg, Va.
COWGILL, H. B., Box 333, Fort Smith, Ark.
DEATRICK, E. P., Kutztown, Pa.
FLORELL, VICTOR H., Plant Introduction Garden, Chico, Cal.
FRENCH, W. L., Austin, Minn.
JUSTIN, M. M., 442 State Capitol, Salt Lake City, Utah.
KENNEY, RALPH, Kansas State Agr. College, Manhattan, Kans.
LUND, VIGGO, Dept. Plant Breeding, Cornell Univ., Ithaca, N. Y.
MARTIN, J. H., Harney Branch Station, Burns, Oreg.
MILNER, F. W., Hartford, Kans.

MOORE, HARVEY L., Leonard Apts., Bellevue & Prospect Sts., Trenton, N. J.
NEWTON, ROBERT, Woodstock, N. B., Canada.
OLSON, P. J., R. F. D. No. 1, Grafton, N. Dak.
OSLER, H. S., Court House, Ann Arbor, Mich.
RUSSEL, J. C., Dept. Chem., Nebr. Wesleyan Univ., University Place, Nebr.
SHINN, E. H., 225 Main Street, Stillwater, Okla.
THOMPSON, G. E., Experiment Station, Tucson, Ariz.
THOMPSON, JAMES, College of Pharmacy, U. of W., Seattle, Wash.
WARBURTON, C. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
WOODARD, JOHN, Mt. Morris College, Mt. Morris, Ill.

## ROLL OF HONOR.

The Society's honor roll of members who are serving their country in its military or naval forces is constantly growing. The list as here printed contains the names of 42 men, but no doubt it is quite incomplete. The editor will appreciate items of interest regarding any of these men, as well as corrections in or additions to the list. News items regarding commissions granted, citations, or other matters are particularly useful. The names so far reported follow.

ALBERT, A. R.,
BLISS, S. W.,
BROCKSON, W. L.,
BRUCE, O. C.,
BRUNSON, A. M.,
BURNETT, GROVER,
CATES, HENRY R.,
CHAPMAN, JAMES E.,
CHILDS, R. R.,
DEATRICK, E. P.,
DE WERFF, H. A.,
DICKENSON, R. W.,
DOWNS, E. E.,
ELLISON, A. D.,
FREEMAN, RAY,
GENTLE, G. E.,
GILBERT, M. B.,
GRAHAM, E. E.,
GRAY, SAMUEL D.,
HOLLAND, B. B.,
HUDELSON, R. R.,
JENSEN, O. F.,
KENWORTHY, CHESTER,
KIME, P. H.,
MACFARLANE, WALLACE,
MOOMAW, LEROY,
NEWTON, ROBERT,
PALMER, H. WAYNE,
PIEMEISEL, R. L.,
PURINGTON, JAMES A.,
QUIGLEY, J. V.,
RATCLIFFE, GEO. T.,
RAYMOND, L. C.,
RICHARDS, PHIL E.,
SCHNEIDERHAN, F. J.,
SCHOONOVER, W. R.,
SCOTT, HERSCHEL,
SMITH, J. B.,
STARR, S. H.,
TABOR, PAUL,
TOWLE, R. S.,
WESTBROOK, E. C.

## NOTES AND NEWS.

Whitney J. Atcheson has been appointed assistant agronomist at the Maryland station.

Ross L. Bancroft, formerly associate professor of soils in the Iowa college, is now in charge of soil extension work in that State.

Percy B. Barker, recently head of the department of agronomy in the University of Arkansas, has been appointed assistant professor of agricultural education in the University of Minnesota.

H. G. Bell, for the past several years with the Chicago office of the American Fertilizer Association, is now in charge of the recently opened Canadian office of the association, at Toronto.

R. Page Bledsoe, formerly of the California station, is now in charge of forage crop work on the recently established station at Waterville, Wash.

H. B. Cowgill, formerly plant breeder of the Porto Rico station, is now in charge of the sorghum sirup investigations of the Department of Agriculture at Fort Smith, Ark.

R. H. Forbes, dean and director of the Arizona college and station, has been granted a year's leave of absence to assist the Société Sultanienne d'Agriculture of Cairo, Egypt, in agricultural war service in the Valley of the Nile.

E. J. Iddings, dean of the Idaho college of agriculture, has been made director of the Idaho station as well.

Robert Newton, formerly field husbandman for the province of New Brunswick, has been in active service in the Canadian army since July, 1915. He is now captain of E Battery, Canadian Anti-Aircraft Service, and is in France.

P. J. Olson, assistant in plant breeding at the Minnesota station, has resigned to engage in farming in North Dakota.

Everett P. Reed, assistant agronomist of the New York State station, has resigned to become a farm bureau agent in Ohio.

W. J. Spillman has resigned as chief of the office of farm management, U. S. Department of Agriculture, a position which he has held for the past sixteen years, to become editor of The Farm Journal, Philadelphia.

G. E. Thompson, formerly agronomist in the extension service in Kansas, is now agronomist of the Arizona station.

P. F. Trowbridge of the department of agricultural chemistry of the Missouri station has been elected director of the North Dakota station and entered on his new duties September 1. He succeeds L. Van Es, resigned to become head of the veterinary department in the University of Nebraska.

R. O. Westley of the Iowa college has been elected assistant professor and A. M. Christensen of North Dakota has been made instructor in farm crops at the Northwest School of Agriculture, Crookston, Minn., succeeding F. L. Kennard and O. M. Kiser, respectively.

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## INTERPRETATION OF FIELD OBSERVATIONS ON THE MOISTNESS OF THE SUBSOIL.[1]


F. J. Alway, G. R. McDole and R. S. Trumbull.


### Introduction.

Soil investigators and agronomists do not appear to have recognized at any time the possible practical importance of field observations on the moistness of the subsoil in dry-land regions as a guide to the more intelligent employment of various cultural operations. As the result of some limited field studies in Saskatchewan in 1904 and 1905, one of us suggested that in that province, where the summer fallow is very extensively employed, the ordinary farmer, provided with a 6-foot auger, could form a fair estimate of the moisture conditions of his fields before the spring was sufficiently advanced to allow seeding. He would thus be in position to decide intelligently whether to sow grain upon his stubble fields or to summer fallow them, instead of being governed by the rule of "one year of fallow followed by two years of grain" (1, p. 339).[2] It was suggested that all progressive dry-land farmers would eventually provide themselves with soil augers so that they might keep themselves informed as to the moisture conditions of their fields (2, p. 42). Later studies in western Nebraska and in the Southwest have made it evident that field observations might be of at least equally great practical importance in these dry regions (3, p. 699).


[1] The work reported in this paper was carried out in 1907 to 1913 while the authors were members of the staff of the Nebraska Agricultural Experiment Station. Received for publication April 6, 1918.


[2] References are to "Literature cited," p. 278.

In the ten years which have elapsed since the publication of these views, there has been no definite recognition of the practical importance of field observations, even by the agronomists of the many dry-land experimental substations in this country. The nearest approach to such recognition is contained in a very recent publication by Chilcott and Cole on "Growing Winter Wheat on the Great Plains," in which it is stated that "a good guide to practice is to sow a large acreage when the soil at seeding time is wet to as great a depth as 3 feet," and that "the depth to which the soil is wet can usually be told easily by inspection, the break between the wet and dry soil being very sharp" (9, p. 4). Regarding the method of inspection they make no suggestions.

Our soil moisture studies in the semiarid portion of Nebraska, in which we made notations on the moisture condition of each foot section of the subsoil as the samples were being taken and later determined both the moisture content and the hygroscopic coefficient (5), have provided data from which to attempt a quantitative interpretation of field observations. The use of the soil auger and a record of field observations upon the occasion of visits to various districts in the drier portions of this country and Canada have served to show that the matter may be of practical importance in all these places. In regions with a humid climate such observations are of much less importance. Thus studies carried out in eastern Nebraska at the same time as those in western Nebraska convinced us that in the former such observations have only a very limited field of usefulness, while later studies made in Minnesota indicate that here they are of still less value.

The moisture condition of a soil may conveniently be expressed by stating both the hygroscopic coefficient and the ratio of the water content to this. Thus, the expression, *hyg. coef.* = *10.0*, *ratio* = *1.7*, indicates a moisture content of 17.0 percent, a wilting coefficient of 15.0[3] (8, p. 65), 5.0 percent of free water, and 2.0 percent of growth water. As the ratios 1.0, 1.5, and 2.0–2.5 appear to indicate, respectively, the minimum to which crop plants can reduce the soil moisture, the point at which root penetration practically ceases (7, p. 278), and the water-retaining capacity of well-drained arable mineral soils (6, p. 69), such an expression makes all these relations apparent at a glance. The ratio when used alone indicates the relative moistness, while its combination with the hygroscopic coefficient expresses the moisture condition.

[3] The exact figure is 14.7.

### Tools for Sampling Dry Subsoils.

Anyone who has become familiar with the use of the ordinary soil auger in exploring the subsoils of humid regions must be struck by the limitations of this tool when he first tries to employ it in the drier lands. Usually, as the auger is withdrawn from the hole the soil slides off and the loosened material, instead of being brought to the surface for inspection, accumulates in the bottom of the boring. At shallow depths, 2 or 3 feet, it is possible by means of a quick jerk of the auger to throw to the surface enough of the loosened subsoil to allow its examination for the purposes of the ordinary soil survey, and by repeating the operation the hole may from time to time be thus cleaned sufficiently to allow the successive levels to be inspected. With increasing depth this device becomes less and less applicable, and is quite useless long before the tenth foot has been reached. It is evident that satisfactory samples of the subsoil can not be taken by any tool that will not permit the withdrawal of the loosened portion without admixture with material from nearer the surface. For exploration purposes this difficulty may be met by carrying along a can of water and from time to time pouring some of it down the hole, the loosened subsoil so moistened being removable without difficulty. This may aid in obtaining samples for chemical analysis, but not for moisture determinations.

The soil tubes invented by King and improved by Briggs allow satisfactory sampling to a depth of 10 feet wherever coarser rock fragments are absent. Even longer tubes may be employed, but the extreme inconvenience of these, especially when they must be carried from place to place, will be evident. A serious objection to the use of soil tubes lies in the inability of the operator to observe the differences in moisture content as the samples are being taken.

A very convenient tool for use at a distance from the laboratory is the sleeve auger or "auger with casing" which Tinsley (10, p. 57) devised soon after he began his soil studies in New Mexico. The essential feature of this is a metal sheath or sleeve which slides down over the bit; as the auger is withdrawn from the boring the loosened material is forced tightly into the sheath and so brought to the surface. By means of this tool samples satisfactory for both chemical and moisture determinations may be taken from the driest subsoil and from any depth. When provided with 2- or 3-foot extensions, it may, like the ordinary auger, be extended to any desired length, and also used without the sheath, if the latter is made removable. In very

dry soils the sleeve is necessary, but in moist soils it is very inconvenient, while between these two conditions there is a stage of moistness in which both the open and the sheathed bit do satisfactory work, although more rapid headway can be made with the former. The complete field equipment for field observations where dry subsoils are involved includes three augers, each 3 feet long, two of them open and of different diameters, the third with a sleeve and of the same diameter as the smaller of the other two. In addition three handles, two small pipe wrenches, some files, and sufficient 3-foot extensions to reach any depth desired are needed. Sufficient tools to sample to a depth of 20 feet can be carried by hand conveniently in a 3-foot case.

## Methods of Sampling.

The purpose of our record of field observations was threefold. In the first place they served to guide the one of us who was doing the sampling, our interest in learning the extremes of moistness found under any given tillage or crop condition being much greater than in ascertaining merely the average moisture conditions. To obtain sets of samples representative of the extremes we often first explored a field without taking samples, later deciding from the notations thus secured where and from what depths to collect the samples to be sent to the laboratory.

In the second place, when only one of us was in the field, these notes served to keep the workers at the laboratory in close touch with the field conditions. Long in advance of the arrival of the samples the men at the laboratory had a far better idea as to the actual moisture conditions being encountered in the field than otherwise would have been possible until after the samples had been dried and subjected to the hygroscopic coefficient determination. The tediousness of the latter is such that under our working conditions many months often elapsed between the taking of the samples and the determination of this value. The indirect method of Briggs and Shantz (8) for obtaining the hygroscopic coefficient from the moisture equivalent was developed by these authors only near the close of our work in Nebraska and even then, had the rather elaborate and costly equipment required been at our disposal, almost as much delay would have been caused as was the case with the direct method. The simpler and more expeditious indirect method, based upon a determination of the hygroscopic moisture (4, p. 351), had not then been developed, it being an outgrowth of our moisture studies.

Lastly, we had it in mind to attempt a numerical interpretation

whenever our data had become sufficiently numerous. This last purpose, however, was subordinated to our real object in the collection of samples, the determination of the relation of the extremes of moisture content to the hygroscopic coefficient. That our main purpose conflicted more or less with the third object mentioned will be pointed out in a later paragraph.

## Field Notations.

The notations as to the relative moistness of the soil, made as the samples were being taken, were indicated by the letters *P, I,* and *M* for "powder," "intermediate," and "moist," respectively. The sleeve was employed only where a sample could not be obtained without it; in such cases the field notation was "P." Where the soil adhered so firmly to the bit that it could be removed from the hole by the ordinary auger without difficulty the condition was recorded as "M." Throughout the work we attempted to distinguish several intermediate degrees of moistness, such as "slightly moist" and "very slightly moist," but as we have found no definite concordance of these

Table 1.—*Relation of field notations to moisture condition in different portions of 12-inch sections, illustrating the difficulty of assigning a satisfactory notation to the foot section as a whole when an abrupt change occurs within it. All the borings were made in a small cornfield on the same day.*

| Boring. | Depth, inches. | Field notation. | Ratio. | Hygroscopic coefficient. |
|---|---|---|---|---|
| 1 | 25–28 | M | 1.7 | |
| | 29–36 | P | 1.1 | |
| | Av. 25–36 | — | 1.3 | [a]10.0 |
| 2 | 13–14 | M | 1.8 | 11.4 |
| | 15–24 | I | 1.5 | 10.0 |
| | Av. 13–24 | — | 1.5 | — |
| 3 | 13–21 | M | 1.8 | 11.5 |
| | 22–24 | P | 1.2 | 10.4 |
| | Av. 13–24 | — | 1.6 | — |
| 4 | 13–22 | M | 1.9 | |
| | 23–24 | P | 1.3 | |
| | Av. 13–24 | — | 1.8 | [a]11.2 |
| 5 | 13–21 | M | 1.7 | |
| | 22–24 | P | 1.2 | |
| | Av. 13–24 | — | 1.6 | [a]10.7 |
| 6 | 13–22 | M | 1.8 | |
| | 23–24 | P | 1.2 | |
| | Av. 13–24 | — | 1.7 | [a]10.9 |
| 7 | 13–18 | M | 1.8 | |
| | 19–24 | I | 1.5 | |
| | Av. 13–24 | — | 1.6 | [a] 8.9 |

[a] The two portions of the foot section had been combined before the hygroscopic coefficient was determined.

differences with the differences in the ratio of moisture content to hygroscopic coefficient we have, for the present purpose, included all of them under the designation "I." It was found that at certain stages of dryness the diameter, etc., of the bit employed seemed to determine whether a soil would slip off, and so be designated "P," or barely adhere when the auger was carefully withdrawn from the boring, and so be indicated as "I." The samples, except where otherwise indicated, were composites from 3 borings made 10 to 20 feet apart.

TABLE 2.—*Field notations on moisture conditions of samples from the three borings used in preparing field composites in representative fields, illustrating the difficulty of assigning a satisfactory notation to composites from sections differing distinctly in moistness.*

| Field. | Boring. | Field notations | | |
|---|---|---|---|---|
| | | First foot. | Second foot. | Third foot |
| A | 1 | M | Upper half, M; lower half, P | P |
| | 2 | M | do. | P |
| | 3 | M | do. | P |
| | Section | M | I | P |
| B | 1 | M | P | P |
| | 2 | M | First 3 in., I; next 9 in., P | P |
| | 3 | M | I | I |
| | Section | M | I | I |
| C | 1 | M | First 3 in., I; next 9 in., P | P |
| | 2 | M | P | P |
| | 3 | M | I | First 3 in., I; next 9 in., P |
| | Section | M | I | I |
| D | 1 | M | M | First 6 in., M; next 6 in., I. |
| | 2 | M | M | First 6 in., I; next 6 in., P. |
| | 3 | M | M | First 3 in., I; next 9 in., P. |
| | Section | M | M | I |

Where at any particular depth the soil in all three borings appeared equally moist the notation to be assigned was evident, but where there were distinct differences the field description was more complicated. Where the upper part of a foot section was moist and the lower "powder," or where the reverse held true, the condition of the whole section was recorded as "I." Where the greater part of the section was moist the ratio would be high, but where the opposite was found the ratio might prove low. This is illustrated by Table 1, in which data are reported from individual borings in which the foot sections showed a sharp break and were separated into two parts for

the moisture determination. The third foot of boring 1 showed a ratio of only 1.3 and the second foot of boring 4 a ratio of 1.8, although both were recorded as "I." In both cases the upper part of the foot was moist and the lower "powder," the ratios in the upper part being 1.7 and 1.9, respectively, and in the lower 1.1 and 1.3.

The matter was still further complicated by the use of composites, for the reason that the depth to which the subsoil had been moistened or dried out varied more or less from place to place and commonly we did not find in any field a uniformly constant depth. The notations on the samples taken from four fields in May, 1912, illustrate this (Table 2). The samples used for the moisture determinations were composites of the whole foot section from 3 borings, but on the foot section of each boring we made separate notations. To have obtained all the data possible for the interpretation of these field notations would have required separate determinations of moisture content and hygroscopic coefficient on 10 samples from the second foot of Fields A, B, and C, instead of on only the three. This was a case where the third of the above-mentioned purposes in making field notations had to be subordinated to the main object of the work.

## Concordance of Notations with Actual Moistness.

Table 3 gives a summary of the data on over a thousand samples from Nebraska, 857 from the southwestern semiarid portion, and 235 from near Lincoln in the eastern humid portion. Of the 587 samples recorded in the field as "P" only 2 percent showed a ratio of 1.5 or 1.6 and none as high as 1.7, while a ratio of less than 1.4 was shown by 95 percent of those from western and by 90 percent of those from eastern Nebraska. Of the samples with the notation "M," 87 percent of those from the western and 91 percent of those from the eastern part of the State showed a ratio above 1.5. Thus approximately 95 percent of those recorded as *M* had a ratio of 1.5 or above and a similar percentage of those recorded as *P* had a ratio of less than 1.4. Thus, 1.5,[4] the computed wilting coefficient of Briggs and Shantz, may be regarded as the approximate dividing point, the soil being readily recognizable as *M* if it is much moister than this and as *P* when it is appreciably drier. This would lead to the conclusion that when sections uniform in moistness are noted as "I" they should be in a moisture condition approximating the ratio 1.5. While all the samples from the eastern part of the State and most of those from the western, 709 out of 857, had a hygroscopic coefficient

[4] To be accurate, 1.47 (8, p. 65).

of 5.0 or above, the number of the coarser-textured soils, 148, is sufficient to indicate that this property is not dependent upon a fine texture.

We have too few data on very fine-textured soils, those with hygroscopic coefficients of 16 to 25, and on the coarser sands, to decide whether or not these differ from the common tillable soils represented in Table 3.

TABLE 3.—*Relation of field notations to the actual moistness, expressed as the ratio of moisture content to hygroscopic coefficient.*

WESTERN NEBRASKA.

| Field notation. | No. of samples. | Percentage of samples with ratio of | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.9 or lower. | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 or higher. |
| (a) Finer textured soils, hyg. coef. 5.0 or higher. | | | | | | | | | | |
| Powder...... | 472 | 23 | 28 | 30 | 11 | 5 | 1 | 1 | 1 | 0 |
| Moist....... | 110 | 0 | 0 | 0 | 0 | 3 | 0 | 8 | 11 | 78 |
| Intermediate | 127 | 0 | 2 | 7 | 23 | 20 | 13 | 10 | 8 | 17 |
| (b) Coarser textured soils, hyg. coef. below 5.0. | | | | | | | | | | |
| Powder...... | 63 | 13 | 22 | 29 | 21 | 1 | 8 | 3 | 0 | 3 |
| Moist....... | 53 | 0 | 0 | 0 | 0 | 2 | 10 | 8 | 4 | 76 |
| Intermediate | 32 | 0 | 0 | 6 | 0 | 3 | 3 | 22 | 25 | 41 |
| (c) All soils sampled. Sum of a and b. | | | | | | | | | | |
| Powder..... | 535 | 22 | 27 | 30 | 11 | 5 | 2 | 2 | 1 | 0 |
| Moist....... | 163 | 0 | 0 | 0 | 0 | 2 | 3 | 8 | 9 | 78 |
| Intermediate | 159 | 0 | 1 | 7 | 20 | 17 | 11 | 13 | 11 | 20 |
| EASTERN NEBRASKA. | | | | | | | | | | |
| Powder...... | 52 | 2 | 4 | 28 | 30 | 27 | 6 | 2 | 2 | 0 |
| Moist....... | 128 | 0 | 0 | 0 | 0 | 1 | 1 | 7 | 5 | 86 |
| Intermediate | 55 | 0 | 0 | 0 | 11 | 13 | 22 | 22 | 10 | 22 |

While the degree of moistness of the subsoils corresponding to the field notation "P" thus appears to be similar in both the semiarid and humid portions of Nebraska, the frequency of occurrence of this dry condition shows a great difference. While in the former it appears to be the prevailing condition of the subsoil, being found in prairies, abandoned lands, alfalfa fields, grain fields after harvest, and at times even in clean cultivated orchards where the trees are still alive and in a fairly healthy condition, in the latter it is rarely found except in the subsoil of well established alfalfa fields.

The various levels of the subsoil have the condition *M* replaced by *P* only through the action of plant roots which have actually penetrated into them. In the semiarid districts those portions of the subsoil found to be *P* when a crop has died of drought, suffered serious injury from lack of water, or matured in a period of rather dry weather, but which previously, either at the time of seeding or sub-

TABLE 4.—*Moisture conditions in fields near Imperial, Nebr., in April, 1911, illustrating relative value of field notations compared with the actual determination of total moisture as an index of the available moisture after a prolonged drought.*

| Depth, feet. | Prairies. | | Sorghum stubble. | Corn stubble. | | | | | Wheat stubble. | | Winter wheat. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | | 1. | 2. | 3. | 4. | 5. | 1. | 2. | |
| | **FIELD NOTATIONS.** | | | | | | | | | | |
| 1 | P | P | M | P | P | I | P | M | P | P | P |
| 2 | P | P | I | P | P | I | P | I | P | P | I |
| 3 | P | P | I | P | P | I | P | I | P | P | I |
| 4 | P | P | I | P | Rock | I | P | I | P | P | I |
| 5 | P | P | I | P | — | I | P | I | I | P | I |
| 6 | P | P | I | P | — | I | P | I | I | P | I |
| | **TOTAL WATER.** | | | | | | | | | | |
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* |
| 1 | 5.4 | 2.3 | 4.6 | 6.9 | 7.8 | 5.2 | 5.6 | 8.3 | 11.0 | 6.8 | 4.6 |
| 2 | 7.5 | 2.4 | 6.0 | 9.4 | 10.8 | 9.8 | 7.7 | 7.0 | 10.9 | 8.1 | 6.5 |
| 3 | 7.0 | 2.2 | 5.4 | 10.3 | 9.5 | 9.1 | 8.2 | 5.6 | 9.6 | 8.0 | 6.2 |
| 4 | 6.1 | 2.4 | 4.1 | 9.7 | — | 10.0 | 9.1 | 10.2 | 10.9 | 8.9 | 4.3 |
| 5 | 4.2 | 2.2 | 8.6 | 7.6 | — | 7.0 | 4.6 | 10.5 | 19.8 | 9.8 | 3.4 |
| 6 | 4.0 | 2.3 | 8.6 | 7.1 | — | 5.3 | 7.8 | 9.9 | 16.8 | 7.4 | 5.9 |
| Av. | 5.7 | 2.3 | 6.2 | 8.5 | — | 7.7 | 7.2 | 8.6 | 13.2 | 8.2 | 5.2 |
| | **HYGROSCOPIC COEFFICIENTS.** | | | | | | | | | | |
| 1 | 6.4 | 2.0 | 2.9 | 6.8 | 7.7 | 3.5 | 6.0 | 4.7 | 13.2 | 6.4 | 3.2 |
| 2 | 7.9 | 2.2 | 4.3 | 9.3 | 10.2 | 7.7 | 7.3 | 4.4 | 11.5 | 7.9 | 4.1 |
| 3 | 8.1 | 2.0 | 4.3 | 9.6 | 8.5 | 6.9 | 7.6 | 3.8 | 9.6 | 8.1 | 4.1 |
| 4 | 6.8 | 2.0 | 3.0 | 9.5 | — | 8.0 | 8.4 | 6.2 | 9.8 | 9.2 | 3.2 |
| 5 | 4.2 | 2.1 | 6.4 | 7.2 | — | 8.5 | 4.0 | 6.2 | 14.9 | 9.6 | 2.2 |
| 6 | 3.9 | 2.0 | 7.1 | 6.4 | — | 3.6 | 6.1 | 5.3 | 12.4 | 7.1 | 3.5 |
| Av. | 6.2 | 2.1 | 4.7 | 8.1 | — | 5.8 | 6.6 | 5.1 | 11.9 | 8.1 | 3.4 |
| | **RATIOS.** | | | | | | | | | | |
| 1 | 0.8 | 1.1 | 1.6 | 1.0 | 1.0 | 1.5 | 0.9 | 1.8 | 0.8 | 1.1 | 1.4 |
| 2 | 0.9 | 1.1 | 1.4 | 1.0 | 1.1 | 1.3 | 1.1 | 1.6 | 0.9 | 1.0 | 1.6 |
| 3 | 0.9 | 1.1 | 1.3 | 1.1 | 1.1 | 1.3 | 1.1 | 1.5 | 1.0 | 1.0 | 1.5 |
| 4 | 0.9 | 1.2 | 1.4 | 1.0 | — | 1.2 | 1.1 | 1.6 | 1.1 | 1.0 | 1.3 |
| 5 | 1.0 | 1.0 | 1.3 | 1.1 | — | 1.3 | 1.1 | 1.7 | 1.3 | 1.0 | 1.5 |
| 6 | 1.0 | 1.1 | 1.2 | 1.1 | — | 1.5 | 1.3 | 1.9 | 1.4 | 1.0 | 1.7 |
| Av. | 0.9 | 1.1 | 1.3 | 1.0 | — | 1.3 | 1.1 | 1.7 | 1.1 | 1.0 | 1.5 |

TABLE 5.—*Moisture conditions at Imperial, Nebr., in May, 1912, illustrating the reliability of field notations after a wet winter following a very dry summer.*

| Depth, feet. | Prairies. | | | | | | Corn stalks. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. | 1. | 2. | 3. | 4. | 5. |
| | FIELD NOTATIONS. | | | | | | | | | | |
| 1 | M | M | M | M | M | M | M | M | M | M | M |
| 2 | I | M | M | M | M | M | M | M | I | M | M |
| 3 | P | M | M | I | P | M | P | M | P | I | M |
| 4 | P | M | M | P | P | P | P | M | P | P | I |
| 5 | P | M | M | Rock | Rock | P | P | M | Rock | Rock | I |
| 6 | P | M | M | — | — | P | P | M | — | — | I |
| | TOTAL WATER. | | | | | | | | | | |
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* | *Pct.* |
| 1 | 16.0 | 4.0 | 7.6 | 16.9 | 12.2 | 7.8 | 17.5 | 8.6 | 18.3 | 17.3 | 14.0 |
| 2 | 16.9 | 5.4 | 10.3 | 18.0 | 14.8 | 11.1 | 17.8 | 8.7 | 17.8 | 17.5 | 12.8 |
| 3 | 11.2 | 7.9 | 9.4 | 15.0 | 9.2 | 10.9 | 13.1 | 8.5 | 10.7 | 13.6 | 9.5 |
| 4 | 6.5 | 6.9 | 8.0 | 10.1 | 6.1 | 4.2 | 12.0 | 10.0 | 10.4 | 10.2 | 8.2 |
| 5 | 5.5 | 5.9 | 4.9 | — | — | 3.7 | 10.5 | 15.6 | — | — | 9.8 |
| 6 | 5.1 | 6.1 | 4.4 | — | — | 3.6 | 6.9 | 21.3 | — | — | 9.0 |
| Av. | 10.2 | 6.0 | 7.4 | — | — | 6.9 | 13.0 | 12.1 | — | — | 10.5 |
| | HYGROSCOPIC COEFFICIENTS. | | | | | | | | | | |
| 1 | 8.2 | 1.6 | 2.6 | 7.1 | 5.8 | 3.2 | 7.1 | 2.4 | 7.2 | 7.1 | 5.5 |
| 2 | 10.2 | 2.6 | 3.7 | 7.5 | 6.3 | 3.2 | 8.3 | 2.6 | 9.6 | 9.2 | 5.9 |
| 3 | 8.9 | 1.9 | 3.5 | 9.7 | 7.1 | 5.4 | 9.4 | 2.6 | 9.5 | 8.7 | 4.4 |
| 4 | 5.3 | 1.5 | 3.5 | 9.0 | 5.1 | 3.7 | 10.0 | 3.0 | 7.0 | 7.0 | 3.7 |
| 5 | 4.7 | 1.3 | 1.6 | — | — | 3.4 | 7.8 | 5.6 | — | — | 4.9 |
| 6 | 4.9 | 1.3 | 1.3 | — | — | 3.0 | 4.5 | 9.3 | — | — | 4.6 |
| Av. | 7.0 | 1.7 | 2.7 | — | — | 3.7 | 7.9 | 4.2 | — | — | 4.8 |
| | RATIOS. | | | | | | | | | | |
| 1 | 2.0 | 2.5 | 2.9 | 2.4 | 2.1 | 2.4 | 2.5 | 3.6 | 2.5 | 2.4 | 2.5 |
| 2 | 1.7 | 2.1 | 2.8 | 2.4 | 2.3 | 3.5 | 2.1 | 3.3 | 1.9 | 1.9 | 2.2 |
| 3 | 1.3 | 4.2 | 2.7 | 1.5 | 1.3 | 2.0 | 1.4 | 3.3 | 1.1 | 1.6 | 2.2 |
| 4 | 1.2 | 4.6 | 2.3 | 1.1 | 1.2 | 1.1 | 1.2 | 3.3 | 1.5 | 1.5 | 2.2 |
| 5 | 1.2 | 4.5 | 3.1 | — | — | 1.1 | 1.3 | 2.8 | — | — | 2.0 |
| 6 | 1.0 | 4.7 | 3.4 | — | — | 1.2 | 1.5 | 2.3 | — | — | 2.0 |
| Av. | 1.4 | 3.8 | 2.9 | — | — | 1.9 | 1.7 | 3.1 | — | — | 2.2 |

sequently, had been found in the condition *M*, may be expected to show a ratio not far from 1.1. On the other hand, if this portion of the subsoil had not been in the state *M* at any time since the crop was planted, and so not in a condition to permit of root penetration, the condition *P* found at its maturity or death may correspond to a ratio as high as 1.5, it being that induced by some preceding crop which

had matured under more favorable conditions of moisture supply in the surface layers.

TABLE 6.—*Moisture conditions in prairies near McCook and Wauneta, Nebr., in the spring of 1911.*

| Depth, foot. | Field notations. | | | | Total water. | | | |
|---|---|---|---|---|---|---|---|---|
| | McCook. | | Wauneta. | | McCook. | | Wauneta. | |
| | March 24. | March 25. | April 4. | | March 24. | March 25. | April 4. | |
| | | | Sample 1. | Sample 2. | | | Sample 1. | Sample 2. |
| | | | | | *Pct.* | *Pct.* | *Pct.* | *Pct.* |
| 1 | P | P | P | P | 7.8 | 7.3 | 8.4 | 8.8 |
| 2 | P | P | P | P | 8.3 | 8.8 | 7.8 | 8.5 |
| 3 | P | P | P | P | 7.8 | 8.7 | 8.4 | 9.0 |
| 4 | P | P | P | P | 7.8 | 8.3 | 9.8 | 8.4 |
| 5 | P | P | P | P | 8.4 | 8.3 | 12.9 | 7.5 |
| 6 | P | P | I | P | 8.9 | 8.5 | 10.4 | 7.5 |
| 7 | P | P | I | P | 8.8 | 8.5 | 9.7 | 7.3 |
| 8 | P | P | I | P | 9.3 | 9.1 | 8.7 | 7.3 |
| 9 | P | P | I | P | 9.3 | 9.3 | 7.6 | 7.5 |
| 10 | P | P | M | P | 9.5 | 9.2 | 6.8 | 7.6 |
| 11 | P | P | M | P | 9.6 | 9.0 | 6.6 | 8.3 |
| 12 | P | P | M | P | 9.5 | 9.3 | 6.7 | 8.2 |
| 13 | — | — | M | P | — | — | 6.8 | 7.8 |
| 14 | — | — | M | P | — | — | 7.0 | 7.3 |
| 15 | — | — | M | P | — | — | 8.9 | 7.8 |
| | Hygroscopic coefficient. | | | | Ratios. | | | |
| | *Pct.* | *Pct.* | *Pct.* | *Pct.* | | | | |
| 1 | 9.6 | 8.7 | 8.7 | 9.0 | 0.8 | 0.8 | 1.0 | 1.0 |
| 2 | 10.5 | 10.1 | 9.2 | 9.6 | 0.8 | 0.9 | 0.8 | 0.9 |
| 3 | 9.1 | 9.6 | 9.1 | 10.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| 4 | 8.3 | 9.0 | 9.2 | 10.0 | 0.9 | 0.9 | 1.1 | 0.8 |
| 5 | 8.1 | 8.6 | 9.6 | 8.8 | 1.0 | 1.0 | 1.3 | 0.9 |
| 6 | 8.1 | 9.0 | 8.3 | 7.7 | 1.1 | 0.9 | 1.2 | 1.0 |
| 7 | 8.1 | 7.9 | 6.6 | 6.7 | 1.1 | 1.1 | 1.5 | 1.1 |
| 8 | 8.3 | 8.6 | 5.7 | 7.3 | 1.1 | 1.1 | 1.5 | 1.0 |
| 9 | 8.1 | 8.4 | 4.9 | 7.0 | 1.1 | 1.1 | 1.5 | 1.1 |
| 10 | 8.1 | 8.4 | 4.4 | 7.0 | 1.2 | 1.1 | 1.5 | 1.1 |
| 11 | 8.1 | 8.6 | 4.0 | 7.9 | 1.2 | 1.0 | 1.6 | 1.0 |
| 12 | 8.1 | 8.6 | 3.7 | 7.4 | 1.2 | 1,1 | 1.8 | 1.1 |
| 13 | — | — | 4.3 | 6.6 | — | — | 1.6 | 1.2 |
| 14 | — | — | 4.2 | 6.5 | — | — | 1.7 | 1.1 |
| 15 | — | — | 5.1 | 6.4 | — | — | 1.7 | 1.2 |

Tables 4, 5, and 6 illustrate to what extent such field observation may afford reliable information. The notations reported in the first part of each table are the record entered in our field note books as the samples were taken, while the corresponding data on hygroscopic coefficient and ratio were first secured some weeks, or at times many months, later. It will be seen that the field notes afforded immediately a reliable basis for further rational sampling for the purposes we had in view.

PRACTICAL APPLICATIONS.

From the preceding data it is evident that in the semiarid portions of Nebraska, a field examination with an auger without any collecting and drying of samples will permit a rather close estimate of the amount of useful moisture in the subsoil, especially where the latter is comparatively uniform in texture and its hygroscopicity is known. A still finer interpretation of the field observations is facilitated by a knowledge of the previous moisture condition, the character of the preceding weather, and the cultural history of the fields concerned.

To illustrate the application let us assume the case of a farmer on loess soil near Wauneta or McCook, who, during a period such as that of 1909–1913, makes use of a 6-foot auger. If at planting time he find both soil and subsoil moist to the full depth of the auger he may sow his seed with the assurance that there is moisture enough, independent of any rainfall, to ensure the growth, or possibly even the maturity, of small grains. If in both soil and subsoil he find only "P" he will foresee that any crops then planted will be entirely dependent upon the rains to follow, while if the surface soil be *M* and the subsoil *P* the seed will germinate but the survival of the plants will be uncertain. Lastly, if the subsoil be *M* and only the surface layer *P* he need await only a rain sufficient to moisten this surface layer. In the case of certain cultivated and garden crops planted in hills he may add enough water to the hill to moisten a very small area from the surface down to the moist subsoil, so that the roots may develop down into the latter and draw upon it for their supply of moisture, the remaining portion of the dry surface layer, that between the hills, being no serious handicap.

If after harvesting the crop or at the time of plowing he find *P* to extend to a depth of 6 feet, and later, after a period of wet weather, find *M* to replace it to a depth of 4 feet, he may safely assume that through the 4 feet the moisture content is from 2.0 to 2.4 times the hygroscopic coefficient. Further, as the latter value in the case of the loess subsoil averages approximately 9.0 and the texture is quite uniform, he may even compute the weight per acre of the maximum amount of available water accessible to the roots of the crops he may plant.

In preparing land for an orchard or tree plantation he would practice clean cultivation or flood it by directed storm-waters until the condition *M* is established to a depth of from 3 to 6 feet. If in a grove or orchard already well established the trees ceased to thrive and he found *I* or *P* a persistent condition of the subsoil he would

prepare against the next tree-killing, dry series of years by a severe pruning of his trees, or still better by a thinning of the stand.

### Condition of "Powder" of Wide Occurrence in Dry-Land Regions.

Numerous sets of samples from nonirrigable lands in New Mexico and Arizona indicated a similar relation of the ratio to the field notations, *P* being even much more prevalent in those States than in western Nebraska.

In field observations unaccompanied by moisture determinations we have found the dry condition *P* to occur very widely on the drier lands of this country and Canada, and might specifically mention Akron and Parker, Colo.; Dalhart and Amarillo, Texas; Great Falls, Forsyth, and Hobson, Mont.; Ritzville and Prosser, Wash.; Pendleton and Echo, Oreg.; Modesto, Clovis, and Delano, Cal.; Indian Head and Moose Jaw, Sask., and Lethbridge, Strathmore, and Medicine Hat, Alta.

In more humid districts, such as Minnesota, the very dry condition indicated by "P" appears to be even more infrequent than in eastern Nebraska, and hence the field observations of less importance.

### Summary.

At the time of taking a large number of samples of soil for moisture determinations, both in semiarid southwestern Nebraska and in the humid eastern portion of the same State, notations were made as to their apparent moistness and from the correlation of these with data later obtained in the laboratory it has been found possible to give the field notations a numerical interpretation, most conveniently expressed as the ratio of the moisture content to the hygroscopic coefficient. When the soil was too dry to be removable from the boring by the ordinary open auger, a condition designated as "powder" or "P," the ratio was 1.3 or lower, whereas when it was moist enough to adhere well to the bit it showed a ratio of 1.5 or above.

In the case of the semiarid soils dealt with, which had hygroscopic coefficients ranging from 2.0 to 14.0 and so represent the common tillable types, the dry condition indicated by "P" was found to be very common. With these the mere field examination with the ordinary soil auger, without any weighing or drying of samples, enables a quite satisfactory estimate of the moistness. Data on very fine-textured soils and on coarse sands were too few to decide whether the field notations on these may be interpreted in the same manner.

With the humid soils the dry condition represented by "P" was

found comparatively rare, being confined chiefly to well established alfalfa fields, and hence in such districts the field notations have only a limited usefulness.

The ordinary mineral subsoils rarely show a ratio above 2.5, roots appear to be unable to penetrate a soil stratum in which the ratio is below 1.5 (i. e., P), and the lower limit to which plant roots can reduce the subsoil moisture is approximately 1.0 or 1.1. Therefore the above method of interpretation gives promise of usefulness in dry-land regions, not only as a convenient field aid for soil investigators and agronomists, but also as a practical method for the county agricultural agents and the more intelligent farmers.

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# HASTENING THE GERMINATION OF BERMUDA GRASS SEED BY THE SULFURIC ACID TREATMENT.[1]

W. E. BRYAN.

Bermuda grass seed is one of the most difficult of all agricultural seeds to germinate. The ordinary blotter method used for germinating such seeds as alfalfa, corn, beans, wheat, etc., gives no results whatever in most cases. Samples sent to the Arizona station from time to time for germination have given rise to the necessity of ascertaining a reliable method for their germination which would give conclusive results in a shorter period than 21 days, the time usually allowed for the germination of these seeds.

The use of sulfuric acid in hastening the germination of seeds having hard and impervious seed coats is well known. The possibility that the slowness of the germination of Bermuda grass seed was likewise due to an impervious seed coat has suggested that a similar treatment with sulfuric acid might also hasten their germination. To test this suggestion the following experiment was carried out.

A sample of Bermuda grass seed from one of the local seed houses was obtained and 12 lots were counted out, each containing 200 seeds. Each lot was treated with sulfuric acid for periods varying from 5 minutes for the shortest time to 60 minutes for the longest time. In treating the seeds each counted lot was placed in a small glass dish and enough sulfuric acid poured over to cover them. A glass rod was used to stir the acid so that all seeds would be quickly immersed. At the end of each treatment the dish containing the seeds and the acid was dipped into a large beaker of water, and the seeds washed into a cambric bag so that the acid was quickly drained away. The bag was then placed under a faucet and allowed to wash for at least 5 minutes so that all trace of the acid was removed. The bag was then turned wrong side out and the treated seeds were spread on an open blotter for germination. This is conveniently arranged by tying a piece of blotting paper over the top of a small circular glass dish about 2½ inches in diameter, the edge of the paper being pressed down the vertical side of the glass dish so that it reaches almost to the bottom and securely tied with a string. This provides a flat surface on top of the circular dish where the seeds are spread

[1] Contribution from the Arizona Agricultural Experiment Station, Tucson, Ariz. Received for publication April 8, 1918.

out. The germinator is then placed in a larger vessel about 5 inches in diameter and about a half inch of water is poured into the larger vessel. The water soon spreads to all parts of the blotter, thus keeping the seeds in contact with a free water surface without excluding the atmosphere from them. The large vessel is then covered and placed in the germinating chamber, where the temperature is kept at 35° F. during the day and permitted to drop down to room temperature during the night. Plate 7, figure 1, shows the blotter as used in these germinations.

The number of seeds germinating in each sample was counted out and recorded every two days throughout the experiment. Table 1 summarizes the results obtained and gives the total germination on the dates indicated at the heads of the columns.

TABLE 1.—*Germination of Bermuda grass seed treated with sulfuric acid for periods of varying length.*

| Sample No. | Time treated, minutes. | Total percentage germinated at each reading. | | | | | |
|---|---|---|---|---|---|---|---|
| | | Second day. | Fourth day. | Sixth day. | Eighth day. | Twentieth day. | Twenty-second day. |
| 1 | 5 | 1 | 51 | 53 | 54 | 54 | 54 |
| 2 | 10 | 1 | 68 | 71 | 71½ | 71½ | 71½ |
| 3 | 15 | 2½ | 64 | 69½ | 71½ | 71½ | 71½ |
| 4 | 20 | 9 | 64 | 66 | 69 | 70 | 70 |
| 5 | 25 | 9½ | 36 | 46 | 49 | 51½ | 51½ |
| 6 | 30 | 5 | 27 | 31½ | 31½ | 33 | 33 |
| 7 | 35 | 3½ | 10 | 22½ | 22½ | 24 | 24 |
| 8 | 40 | 2 | 12 | 19 | 19 | 19 | 19 |
| 9 | 45 | 0 | 2 | 9 | 14½ | 16½ | 16½ |
| 10 | 50 | 0 | 1 | 3½ | 6 | 6 | 8½ |
| 11 | 55 | 0 | 1 | 5 | 6½ | 6½ | 7 |
| 12 | 60 | 0 | 2 | 5 | 9½ | 11 | 11½ |

In comparison with the above, the highest germination from five untreated lots was 4½ percent on the tenth day, 16 percent on the fifteenth day, and 22½ percent on the twenty-first day.

Table 1 shows:

1. That the lot treated for 10 minutes gives the quickest germination in quantities sufficiently large for obtaining comparative results.

2. That samples treated from 10 to 20 minutes give approximately the same germination in four days, and that these samples run fairly close throughout the entire germinating period.

3. That 95 percent of the total germination of sample No. 2 was obtained at the end of the fourth day.

4. That the highest percentage of germination obtained from any one of the untreated lots was 22½ percent in 21 days.

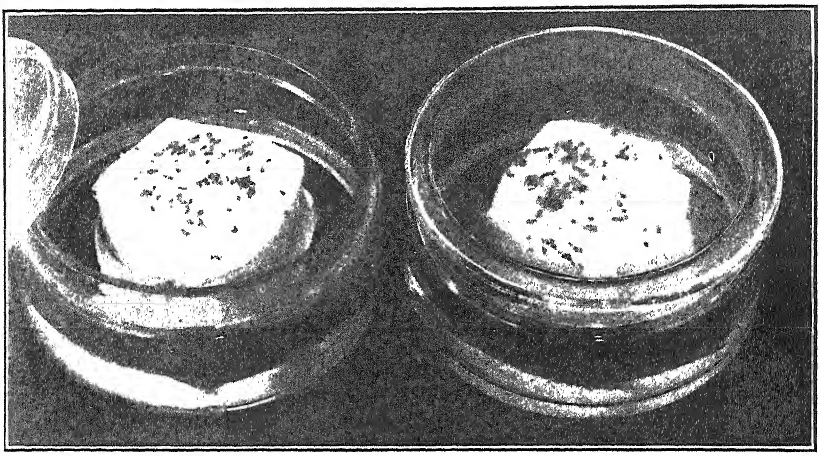

FIG. 1. Blotters in damp chambers as arranged for germination of Bermuda grass seed.

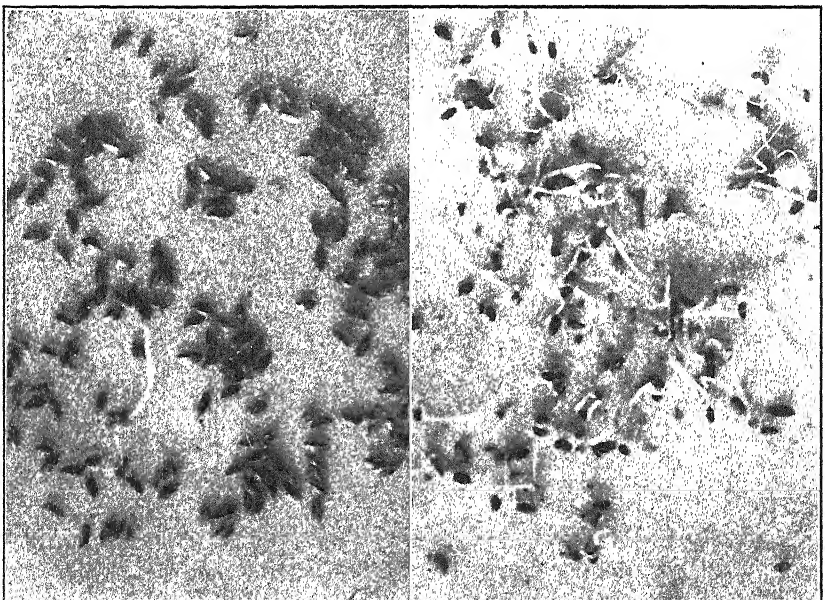

FIG. 2. Bermuda grass seed four days after setting for germination; at the left, untreated, 1 percent germinated; at the right, treated for 10 minutes. 68 percent germinated.

Plate 7, figure 2, shows the results of germination after four days in an untreated lot and in a lot which was treated for ten minutes. The untreated lots germinated only 1 percent, while the lot which had been treated for 10 minutes had germinated 68 percent.

It therefore seems that this method may be used to considerable advantage in saving time in making germination tests. As 95 percent of the seeds are germinated in four days by this treatment, and only 22½ percent were germinated in the untreated sample at the end of 21 days, it seems possible by this method to get a better estimate of the viability of the seeds in four days than with untreated seeds which have run throughout the entire period usually allotted by seed analysts to the germination of Bermuda grass seed.

# THE DECOMPOSITION OF ORGANIC MATTER IN SOILS.[1]

Fred G. Merkle.

## Introduction.

### OCCURRENCE OF CARBON COMPOUNDS.

Carbon compounds are universally distributed in all agricultural soils. They are ever being produced and consumed in the natural cycle of the element. The sources of gain in relation to soils are:

1. By bacteria;
2. By green plants;
3. By rains and snows;
4. Absorption of the gas;
5. Rise of carbon dioxide from below.

1. Bacteria are usually regarded as liberators rather than fixers of the element carbon, yet species have been isolated which perform the latter function. Kaserer (15)[2] demonstrated the production of organic matter by bacteria growing in inorganic media in an atmosphere containing carbon and hydrogen. The work was confirmed by Nabokish and Lebendeff (28), who showed the disappearance of hydrogen and carbon accompanying their fixation.

2. It is generally, not universally, assumed that green plants take all their carbon from the air. Thus a green crop plowed under will add 300 to 1,000 pounds of organic matter per acre (dry basis) or

[1] Thesis submitted for the degree of M.Sc., Massachusetts Agricultural College, Amherst, Mass., June, 1917. Received for publication March 3, 1918.

[2] Numbers in parentheses refer to "Literature cited," p. 300.

approximately 0.04 percent. Green plants are, undoubtedly, the greatest source of gain, yet the amount is small in relation to that already existing in the soil. Even poor soils may contain 60,000 pounds per acre.

3. Rains and snows wash $CO_2$ from the air, probably combined with $NH_3$ as ammonium carbonate. Schumacher (38) gives the $CO_2$ content of rain water as 0.3 to 1.0 volume in 1,000 of rain. Thus, a region having a 36-inch rainfall would annually receive from 400 to 1,500 cubic feet or from 50 to 175 pounds of $CO_2$. Such a figure seems very small, yet it helps to compensate the numerous losses.

4. Soils have an absorptive power for gases, especially carbon dioxide and ammonia. Ferric hydrate, alumina hydrate, humus, and clay appear to be the most active soil constituents as regards absorption of $CO_2$. Reichardt and Blumtritt (34) determined the volume of gas absorbed by equal volumes of various substances and the percentage of $CO_2$ contained as follows:

| Material. | Total gas absorbed by 1,000 grams. | Percent $CO_2$ by volume. |
|---|---|---|
| Charcoal | 164 | 0 |
| Peat | 102 | 51 |
| Garden soil | 14 | 33 |
| $Fe(OH)_3$ | 375 | 70 |
| $Fe_2O_3$ | 39 | 4 |
| $Al(OH)_3$ | 69 | 59 |
| Clay, moist | 29 | 34 |
| Silt | 40 | 32 |
| $MgCo_3$ | 729 | 29 |
| $CaSO_4 \cdot 2H_2O$ | 17 | 0 |

The constituents found abundant in clay, viz., iron and alumina as hydrates, show a strong absorptive power for $CO_2$. Peat is relatively high. Von Dobeneck (42) obtained the following results:

| Material. | $CO_2$ absorbed. |
|---|---|
| Quartz, 100 grams | 0.023 gram |
| Kaolin, 100 grams | 0.261 gram |
| Humus, 100 grams | 1.773 grams |
| $Fe(OH)_3$, 100 grams | 5.054 grams |

If we let quartz represent sand and kaolin clay and combine the results of Reichardt and Blumtritt with those of von Dobeneck it is safe to conclude that the soil's absorptive capacity for $CO_2$ is largely due to its clay and humus content and to the state of its iron compounds.

To show that soils actually do take on carbon by absorption the

results of Lemmermann (22) may be cited. He allowed a kilogram of soil to incubate for a period of eight weeks, determining the total carbon at the beginning and end of this period. An increase of 0.33 gram was observed in one instance and 0.02 gram in another.

5. Many carbon-containing deposits exist within the earth's crust. Just how much carbon may come to the surface from these deposits can not be determined, but it is probable that methane produced below may gradually rise to the surface and upon reaching better aerated conditions, be oxidized to $CO_2$. The deeper soil layers contain greater quantities of $CO_2$ than the surface layers. Ebermayer (8) gives the following figures at 15 and 70 cm. respectively:

| Location. | $CO_2$ content at different depths. At 15 cm. | At 70 cm. |
|---|---|---|
| Beech woods | 0.62 per cent. | 1.19 per cent. |
| Pine woods | 1.13 per cent. | 9.39 per cent. |
| Moss | 1.93 per cent. | 7.98 per cent. |
| Sod | .60 per cent. | 4.13 per cent. |
| Bare ground | 1.19 per cent. | 7.02 per cent. |

Pfeffer (29) gives the $CO_2$ content of the soil air at a depth of 6 meters as 8 percent or more.

While it is possible that the increased amount of carbon dioxide in the lower layers is due to the downward flow of the gas, it is more probable that it is diffusing up from below, in which case it would be an additive agent.

## SOURCES OF LOSS OF CARBON FROM SOILS.

Soils may lose carbon (1) through leaching, (2) through evolution of $CO_2$, and (3) through possible removal by crops.

That soils under certain conditions decrease in organic content is frequently observed. Walker (43) reports a decrease in humus content on nonrotated fields as follows:

| Crop. | Percent humus. 1895. | 1905. | Difference. |
|---|---|---|---|
| Corn continuous | 3.23 | 2.96 | —0.27 |
| Mangels continuous | 3.03 | 2.86 | —0.18 |

Rotated fields and fields growing legumes continuously showed a slight gain in the ten-year period.

Mooers, Hampton, and Hunter (27) show that only when the crop is removed can a decrease in humus content be expected.

1. *Loss through Leaching*—Soils have a strong absorptive power for organic matter; therefore, little or no carbon is lost in that form. The small amount of organic matter soluble in the presence of soil

was shown by Sutton (40). He analyzed the surface water of cultivated fields and found it to contain but 0.4 part of organic matter in 100,000, a seeming insignificant amount. If organic matter were subject to loss by leaching we would expect the subsoil of a continuously manured plot to contain more carbon than that of a nonmanured plot. Such is not the case. Dyer (7) shows that the subsoil of a plot manured for 50 years contains no more, even less, carbon than that of a plot undunged for 41 years. The difference is within the limit of error.

| Condition. | Carbon in third 9-inch layer of soil. |
|---|---|
| Dunged 9 years, undunged 41 years | 0.515 per cent. |
| Dunged 50 years | 0.492 per cent. |

To be capable of leaching, organic matter must be soluble and when in solution it is easily precipitated by bases.

Carbon as bicarbonate of lime is easily lost, as is shown by frequent analyses of drainage waters from limed fields (12).

2. Some carbon may be lost through evolution of $CO_2$, but if any the amount must be slight.

3. To say that plants may remove carbon from the soil may seem contrary to our teachings, yet there are numerous evidences that plants may derive a part, at least, of their carbon through their roots.

It has been observed at the Rothamstead station that poor crops of wheat due to unfavorable climatic conditions have higher percentages of ash elements than good crops. Hence minerals do not seem to be limiting factors. Cameron (4) uses this argument to prove that the use of mineral fertilizers is largely to neutralize toxic substances, but it could be used equally well to show that the synthesis of organic matter as well as the assimilation of minerals is an important factor in plant growth.

To show the value of organic matter in aqueous extracts of poor soils the Bureau of Soils, according to Cameron (5), used a manure extract as follows: One portion of the extract was evaporated and ignited to destroy the organic matter. The other part was used without ignition. The solution to which the unignited manure extract was added gave a far superior growth. Cameron attributes the value of the organic matter in the extract to its probable absorbent action on toxic substances, but it is also probable that the plants absorbed certain organic nutrients from it.

Gardner (11) determined the effect of many substances, mineral and organic, on transpiration and upon the amount of green matter

produced per unit of water transpired. The following figures give the summarized results of many trials:

| Material added. | Growth due to fertilizer. | Growth per unit of water transpired. | Transpiration per unit of growth. |
|---|---|---|---|
| Nothing, check | 100 | 100 | 100 |
| P | 104 | 103 | 97.0 |
| K | 113 | 107 | 93.6 |
| KP | 118 | 108 | 92.6 |
| Lime | 127 | 103 | 97.0 |
| N | 145 | 116 | 86.2 |
| NP | 144 | 119 | 84.0 |
| NPK | 152 | 123 | 81.3 |
| NK | 154 | 125 | 80.0 |
| NPK lime | 173 | 129 | 77.5 |
| Manure | 193 | 135 | 74.0 |
| Clover and lime | 197 | 143 | 69.9 |

It will be noted that the last two treatments, which are organic, not only gave the greatest growth, but gave the greatest growth per unit of water transpired. This work was done with soil solutions so the effects of the organic matter can not be due to its action on the physical condition of the soil, nor to its solvent action upon minerals. It is fair to conclude that the presence of carbon in the soil solution decreases the transpiration necessary to produce a unit of dry matter, a strong indication that plants may assimilate carbon through their roots.

Quarrie (32) reports large increases in garden crops through the application of carbon dioxide to the soil through pipes. Bornemann (2) reports like results with spinach. Mitscherlich (24), on the other hand, obtained no increase from the application of water saturated with $CO_2$. The possibility of adding an excess of water or of gas renders the results inconclusive. We know that in ordinary practice $CO_2$ producing materials are seldom injurious.

De Saussure (6) compared the growth of plants in pure water with water containing one-fourth its volume of carbon dioxide and found that the carbonated water was injurious to growth in the early stages, but not so later in the life of the plant. At the conclusion of the experiment the plants grown in the carbonated water weighed 46.4 grams, while those growing in pure water weighed 45.5 grams.

Hellreigel and Wilfarth (13), Franke (9), Berthelot (1), and Schlössing and Laurent (37) all report the utilization of organic nitrogen by green plants. Schreiner and his associates (39) have isolated creatinine, an organic nitrogen compound, from soils and proved its beneficial action upon plant growth. Lefèvre (18) grew plants in an artificial soil made from sand and moss, supplied with amids and sterilized so that further oxidation of these compounds would be

avoided. The entire plant was enclosed in an atmosphere freed from carbon dioxide. Under such conditions it is evident that any growth must result from the assimilation of the amids. Lefèvre obtained normal growth and concludes that: 1. In a soil supplied with amids one may develop green plants without carbon dioxide. 2. The growth thus produced is a real synthesis, not a *pousée aqueuse* (19). 3. Without light, synthesis from amids is impossible (20).

So much for nitrogenous organic substances. Molliard (25), using glucose, and Laurent (17) and Knudson (16), using other carbohydrates, have shown that plants assimilate sugars and that these sugars are used to synthesize dry matter.

Ravin (33) compared the effects of organic acids with their acid and neutral salts and concluded that such organic acids as malic, tartaric, citric, succinic, and oxalic may be assimilated by plants and further that these organic acids are more nutritive than their corresponding neutral salts or acid salts.

So far we have considered the assimilation of carbon from materials of known composition, namely, $CO_2$, amids, carbohydrates, and organic acids. Molliard (26), to put the matter on a more practical basis, experimented with humus extracted from soil. The work was carried on under sterile conditions, but it was impossible to prevent entirely the evolution of $CO_2$; therefore, definite conclusions can not be drawn.

The most conclusive proof that green plants can take up carbon compounds through their roots is their growth with the foliage enclosed in an atmosphere entirely devoid of carbon dioxide. Pollacii (30) grew plants in a culture bottle within a large receptacle, each being provided with tubes so that the water or air in each may be renewed and controlled independently of the other. The plants were sealed into the stopper with wax. By adding $CO_2$ to the nutrient solution and excluding it from the aerial portions of the plant he has successfully grown plants and even revived the chlorophyl in etiolated leaves.

From the evidence in the foregoing pages it may be concluded that green plants can, and probably do, take carbon through their roots. Just what form or what proportion of the total carbon in the plant this may be can not be stated, but the fact itself is enough to make us turn our attention to the soil organic matter.

DECOMPOSITION OF ORGANIC MATTER.

Hopkins (14) states that "It is the decay of organic matter and not the mere presence of it that gives life to the soil. Partially decayed peat produces no such effect upon the productive power of the soil as follows the use of farm manures or clover residues." Löhnis (23) declares that the organic matter is the life of the soil and upon its decay depends the fertility of the soil.

Realizing the importance of organic matter and its decomposition with reference to soil fertility, many investigations have been made to demonstrate the rate of decay and the factors influencing it.

Van Suchtelen (41) has used the rate of decay, measured by carbon-dioxide production, as a measure of bacterial activity. This method recognizes $CO_2$ as the ultimate and most representative end product of decay. He showed the influence of moisture and of frost, the effect of soluble sugars and of salts on bacterial activity. His results showing the action of fertilizers on the rate of decay are closely related to our subject and will be reported. He mixed the materials in 6 kg. of soil and determined the amount of carbon dioxide produced in 12 hours. His results were as follows:

| Materials used | $CO_2$ produced. |
|---|---|
| 6 kg. soil, no addition | 145 mg. |
| 6 kg. soil + 90 gr. $MgSO_4H_2O$ | 408 mg. |
| 6 kg. soil + 6 gr. CaO | 62 mg. |
| 6 kg. soil + 30 gr. $(NH_4)_2SO_4$ | 864 mg. |
| 6 kg. soil + 6 gr. superphosphate | 306 mg. |

The increases from applied materials are quite large with the exception of lime, which has evidently absorbed the gas produced. One function of fertilizers may be to hasten the decay of organic matter.

Lemmermann (21) and associates worked with the influence of lime compounds on decay. They compared the oxide and carbonate. They found that $CO_2$ production could not be taken as a measure of bacterial action with lime, because the oxide absorbed and the carbonate gave up $CO_2$. To offset the difficulty they carried on balance experiments in which the total carbon was determined before and after the incubation period, which lasted eight weeks. Their experiments show that (a) lime hastens decay, (b) kainit and a mixture of kainit and superphosphate do not increase decay, and (c) dry organic matter decays as rapidly as the same material fresh.

Potter and Snyder (31) report some work along this line. In their experiments the soil was placed in pots under bell jars and the $CO_2$ evolved was measured by drawing air over, not through, the soil. Their observations will be mentioned later.

Fred and Hart (10) showed that sulfate of ammonia, sulfate of potash, and phosphates increased the carbon-dioxide production, the first named to a marked degree.

Russell (36) measures oxidation by determining the oxygen absorbed rather than the $CO_2$ produced. Either method should give about the same results, for many analyses show that a high oxygen content of soil air is accompanied by a low $CO_2$ content and vice versa. In other words, the sum of the oxygen and carbon dioxide is nearly constant. Russell's method is to place the soil in a flask, connected on one side to a KOH flask and on the other side to a mercury tube. The KOH absorbs any $CO_2$ evolved and the rise of mercury in the other arm indicates the oxygen absorbed. He determined the oxidation of many soils by this method and concluded that in different soils of the same type the rate of oxidation varies in the same way as the fertility and may be used as a measure of it. This, if true, is important, for we have no other laboratory method of determining the relative fertility of soils.

## Experimental.

The work of previous investigators indicates oxidation to be a measure of fertility in soils; hence, the rate of oxidation of organic additions should be a measure of their effectiveness. For the purpose of comparing organic materials ordinarily added to the soil the following series of experiments were planned.

For determining the rate of oxidation quart milk bottles were used. They were fitted with 2-holed rubber stoppers, one hole carrying a short glass tube while the other carried a tube reaching to the bottom of the bottle. Both tubes were fitted with short rubber connections stopped with glass plugs. Two hundred grams of washed gravel were placed in the bottom of the bottle to facilitate aeration and afford a space for the excess $CO_2$. The organic substance used in the test was thoroughly mixed with 300 grams of moist soil (25 percent water) and placed on top of the gravel. The soil was moderately compacted by tamping.

The soil used was a fine, sandy loam of alluvial formation which had been under cultivation for many years. It was stored in covered ash barrels and not allowed to dry out, so the original bacterial flora was sufficient for the work. To make sure of this one bottle was inoculated with 10 c.c. of a manure suspension. This bottle gave the same amount of $CO_2$ as the uninoculated one after the first week of incubation, showing that there was no deficiency of organisms.

The rate of oxidation was determined by measuring the amount of $CO_2$ produced each week, as follows. The rubber connections were closed with pinch cocks, the glass plugs removed and the bottles connected with the absorption bottles as shown in figure 41. First is an absorption bottle (A) containing NaOH to free the incoming air of $CO_2$. Next is the incubation bottle (B) with its outlet tube reaching the bottom to make sure of complete removal of the $CO_2$ produced. The absorption apparatus (C) was devised to take the place of a Reisset (35) absorption tower. The tower (D) is an ordinary 100 c.c. pipette filled with broken glass or beads to increase the absorption surface. The pipette is connected with a Chapman filter pump. It was found that a rapid stream of air could be drawn through this tower without danger of incomplete absorption, and also that four minutes of strong aspiration was sufficient to remove all $CO_2$ from the generating flask.

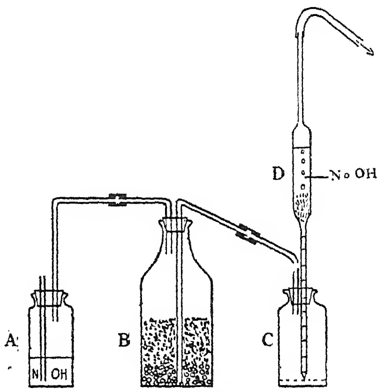

FIG. 41. Apparatus used in the experiments. See description in text.

Each bottle was aspirated once a week, using 50 c.c. of N/2NaOH as the absorbent. The $CO_2$ was determined by the double titration method (3). A 10 c.c. aliquot of the carbonated soda is titrated with phenolphthalein against HCl, first using normal acid until near the neutral point. Neutralization is completed with N/10 acid. This marks the conversion of carbonate to bicarbonate, neutral to phenolphthalein.

$$Na_2CO_3 + HCl + \text{phenolphthalein} \rightarrow NaHCO_3 + NaCl.$$

The amount of acid needed to make this change need not be known, nor is it necessary to know the normality of the alkali used.

Methyl orange is now added and N/10HCl run in drop by drop till the neutral point is reached. The exact amount is recorded and is equivalent to the $CO_2$ contained.

$$NaHCO_3 + HCl + \text{methyl orange} \rightarrow NaCl + H_2O + CO_2.$$

One cubic centimeter of N/10HCl equals 4.4 milligrams of $CO_2$.

Cochineal gives about the same results as methyl orange, but the latter was used throughout this work.

EXPERIMENT I, LEGUME FODDERS.

Soybeans, alfalfa, and red clover were used in this experiment. The plants were cut off at the surface of the ground when in full bloom or as near that stage as possible. They were dried, slowly at first and later in the oven. When dry they were ground and reground until all the material would pass through a 2-mm. sieve. Fifteen grams were mixed with 300 grams of moist loam, placed in the incubation bottles on top of a layer of gravel and slightly compacted. The bottles were stoppered and the outlet tubes closed with glass plugs. They were allowed to incubate in the dark at room temperature, the $CO_2$ produced being measured weekly (usually) in the manner just described. An untreated soil served as a check for all the following experiments. The results are shown in Table 1.

TABLE 1.—*Milligrams of $CO_2$ given off from untreated soil and from soil to which various legume fodders were added.*

| Date. | Loam 300 gr. untreated. | Loam 300 gr. + soybean fodder 15 gr. | Loam 300 gr. + alfalfa fodder 15 gr. | Loam 300 gr. + red clover fodder 15 gr. |
|---|---|---|---|---|
| Nov. 15 | 35.2 | 475.2 | 444.4 | 426.8 |
| Nov. 22 | 33.0 | 385.0 | 336.6 | 325.6 |
| Nov. 29 | 50.0 | 211.0 | 242.0 | 154.4 |
| Dec. 6 | 52.0 | 213.4 | 281.6 | 195.8 |
| Dec. 13 | 37.4 | 167.4 | 200.2 | 182.6 |
| Dec. 21 | 48.4 | 206.8 | 228.8 | 206.8 |
| Dec. 28 | 50.6 | 237.6 | 193.6 | 162.8 |
| Jan. 10 | 41.8 | 191.4 | 189.2 | 132.0 |
| Jan. 17 | 37.4 | 195.8 | 167.2 | 143.0 |
| Jan. 28 | 28.6 | 167.2 | 158.4 | 162.0 |
| Feb. 6 | 35.2 | 160.6 | 165.0 | 169.4 |
| Totals | 449.6 | 2611.4 | 2607.0 | 2261.2 |

The results shown in Table 1 are plotted in figure 42. They show that a rapid production of $CO_2$ takes place the first two weeks after a legume fodder starts to decay, and that after the second week they settle down to a steady rate of decomposition. Apparently red clover decays a little slower than the other fodders, but there is no great difference between them.

There are possibilities of errors in the aspiration of the gas, but the irregularities in the curves are not due to these. Temperature changes affect all alike, hence the general tendency is for all to rise and fall at the same period, though not always in the same degree. The uniformity of the check indicates the accuracy of the method. Duplicates were run in the early part of the experiment but the close agreement seemed to justify dropping them to save work.

*Humus Production.*—Equally important as the rate of oxidation is the humus produced. A substance may oxidize very rapidly, as, for example, sugars, and still not increase the humus content noticeably. Such substances would be of questionable value as regards the physical improvement of the soil. Unpublished work by the writer shows that sugars break up very rapidly in the soil and are nearly com-

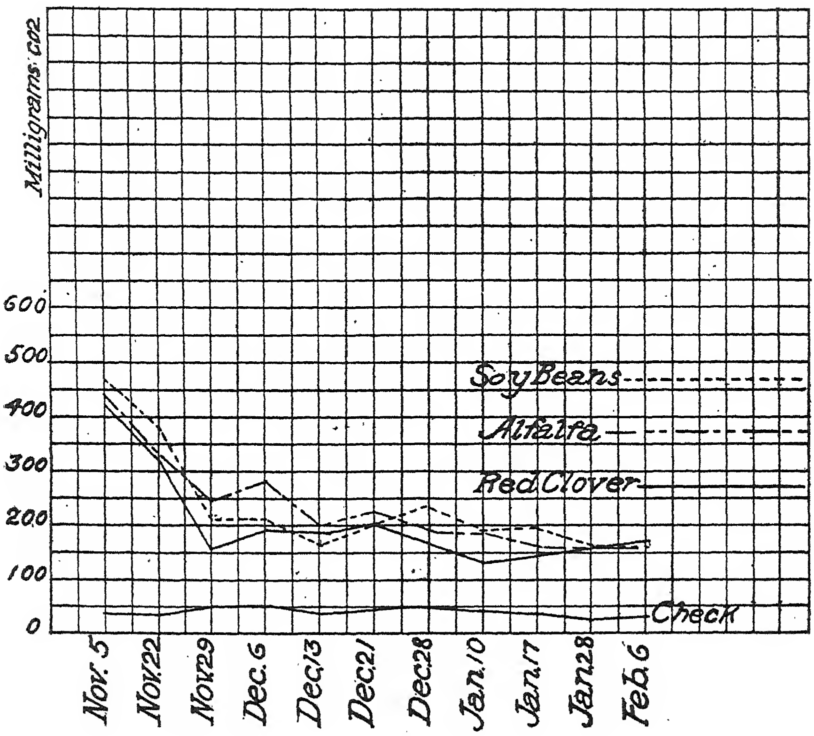


FIG. 42. Graph showing $CO_2$ given off during various periods from untreated soil and from soil to which various legumes were added. (Data from Table I.)

pletely oxidized within a week or two. Lactose, maltose, saccharose, dextrose, and fructose run about the same. Sugar beets (figure 43) in the early stages of decay show the effect of their sugar, but later gave about the same results as rape and swedes.

The materials used in the $CO_2$ production experiments, having been allowed to incubate from November 8 to February 19, were removed, dried, and their humus content determined by the official method. The results are recorded below, together with the total $CO_2$ production for comparison.

| Treatment. | Humus, percent. | Total $CO_2$, cg. |
|---|---|---|
| Soil, no treatment | 2.96 | 44 |
| Soil + alfalfa | 3.43 | 260 |
| Soil + red clover | 3.29 | 220 |
| Soil + soybeans | 3.28 | 261 |

The figures indicate that there is little choice between the legumes in decay and humification.

### EXPERIMENT 2, ROOT CROPS AND RAPE.

Root crops and rape were used to compare readily decomposable carbohydrates, as found in plants, with more inert materials. For this purpose sugar-beet roots, swede or rutabaga roots, and rape tops were used. All of these contain some form of stored food, sugar or starch. The plants were taken from the field, air dried, then oven dried, and ground fine enough to pass a 2-mm. sieve. Fifteen grams of each were mixed with 200 grams of moist soil and placed in incubation bottles as previously described. Determinations of $CO_2$ produced were made weekly. The results are shown in Table 2 and are also shown graphically in figure 43.

TABLE 2.—*Milligrams of $CO_2$ given off from untreated soil and from soil to which sugar beets, rutabagas, and rape were added.*

| Date. | Loam 300 gr. untreated. | Loam 300 gr. + sugar beets 15 gr. | Loam 300 gr. + rutabagas 15 gr. | Loam 300 gr. + rape 15 gr. |
|---|---|---|---|---|
| Nov. 15 | 35.2 | 550.0 | 464.2 | 400.4 |
| Nov. 22 | 33.0 | 708.4 | 484.0 | 396.0 |
| Nov. 29 | 50.0 | 213.4 | 261.8 | 231.0 |
| Dec. 6 | 52.0 | 235.8 | 226.6 | 244.2 |
| Dec. 13 | 37.4 | 171.6 | 162.8 | 165.0 |
| Dec. 21 | 48.4 | 132.0 | 189.2 | 206.8 |
| Dec. 28 | 50.6 | 160.0 | 165.0 | 182.6 |
| Jan. 10 | 41.8 | 125.4 | 147.4 | 158.4 |
| Jan. 17 | 37.4 | 103.4 | 132.0 | 110.0 |
| Jan. 28 | 28.6 | 118.8 | 114.4 | 149.6 |
| Feb. 6 | 35.2 | 106.8 | 140.8 | 156.2 |
| Totals | 449.6 | 2625.6 | 2488.2 | 2400.2 |

Sugar beets, as might be expected, show rapid decay at the start but the sugar is all oxidized in two weeks, after which time the organic matter in them is no more decomposable than that of other materials. Rutabagas contain but little sugar and decay no faster than legume fodders. Rape is slowest at first but as time goes on it exceeds the others.

Comparing the legumes with roots we find that the former are

more readily oxidized as time goes on, that is, after the sugar in the roots is broken down.

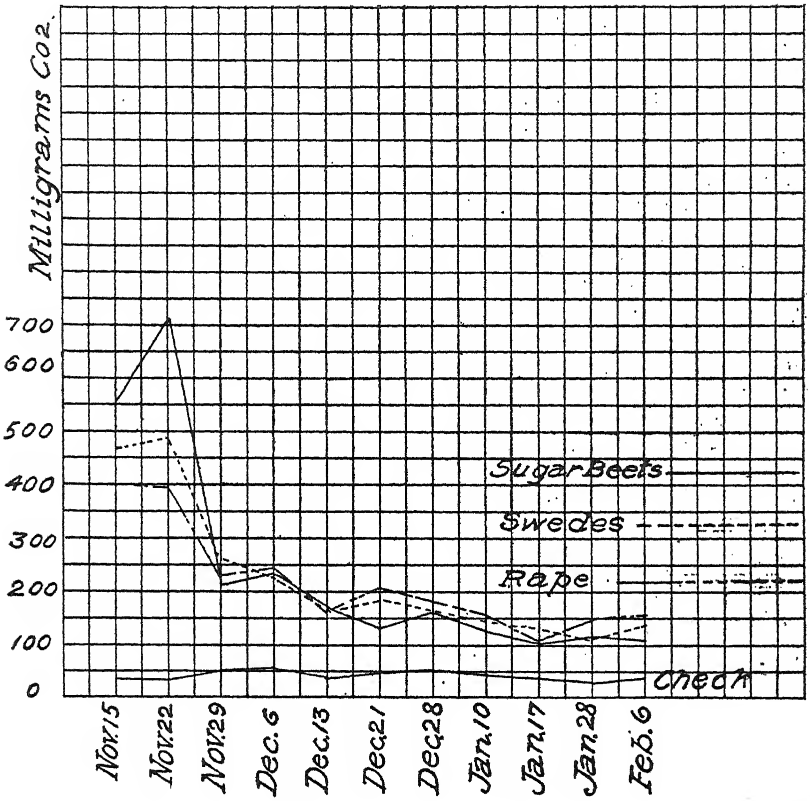


FIG. 43. Graph showing $CO_2$ given off during various periods from untreated soil and from soil to which sugar beets, rutabagas and rape were added. (Data from Table 2.)

The results of the humus determinations are as follows:

| Treatment. | Humus, percent. | Total $CO_2$, cg. |
|---|---|---|
| Soil, no treatment | 2.96 | 44 |
| Soil + swedes | 3.56 | 248 |
| Soil + sugar beets | 3.28 | 262 |
| Soil + rape | 3.24 | 240 |

The difference as shown by the humus figures seems the more representative, since the higher $CO_2$ production for sugar beets is due to the sugar. Rape falls in third place in both instances.

EXPERIMENT 3, LITTERS.

The materials listed below find their way into the soil through natural agencies or as litters and were selected with the expectation of obtaining large differences. It was thought that pine needles might even lower the bacterial activity, at least for a time.

Pine needles, oak leaves, and maple leaves were picked while still

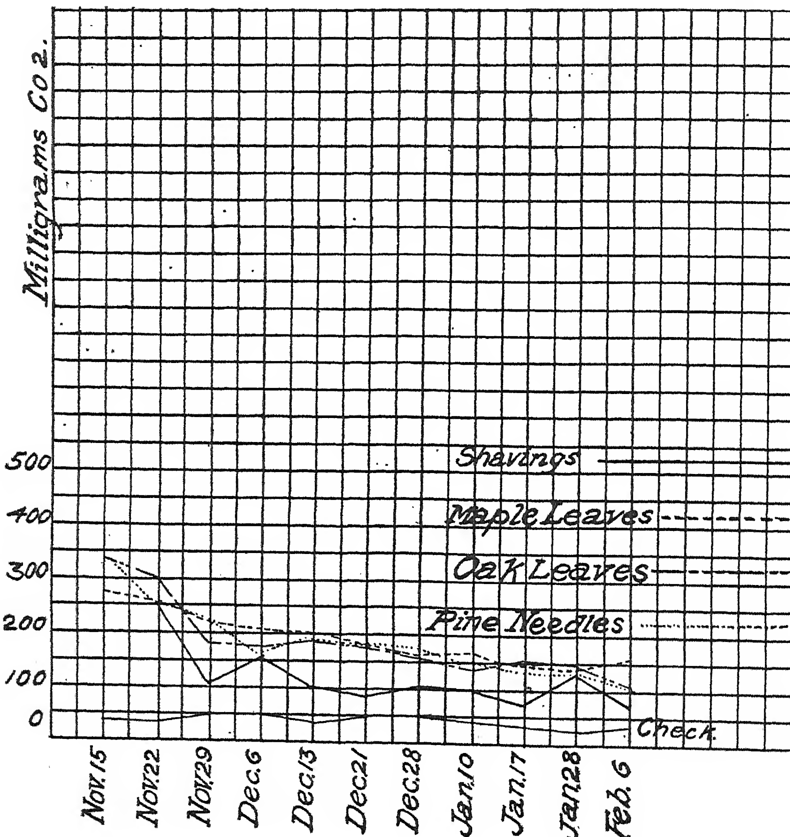


FIG. 44. Graph showing $CO_2$ given off during weekly periods by untreated soil and soil to which various litters were added. (Data from Table 3.)

green, air dried and later oven dried. White pine shavings, as used for litter, were oven dried. Each substance was ground and sieved. Fifteen grams were used in each case. The $CO_2$ determinations are shown in Table 3 and graphically in figure 44.

White pine shavings stand out as a striking example of an inert substance, being lowest and slowest in $CO_2$ production. Maple leaves give a more uniform decline than anything else.

The litters in general, as might be expected, are not as rapidly decomposed as either legumes or root crops and suggest the importance of nitrogen as an aid to oxidation, as those materials which are low in nitrogen are slow to oxidize. This latter statement applies to the later stages of decomposition.

TABLE 3.—*Milligrams of $CO_2$ given off from untreated soil and from soil to which various litters were added.*

| Date. | Loam 300 gr. untreated. | Loam 300 gr. + shavings 15 gr. | Loam 300 gr. + maple leaves 15 gr. | Loam 300 gr. + oak leaves 15 gr. | Loam 300 gr. + pine needles 15 gr. |
|---|---|---|---|---|---|
| Nov. 15..... | 35.2 | 257.4 | 275.6 | 338.8 | 343.2 |
| Nov. 22..... | 33.0 | 257.4 | 250.8 | 303.6 | 259.6 |
| Nov. 29..... | 50.0 | 118.8 | 224.4 | 182.6 | 224.4 |
| Dec. 6..... | 52.0 | 156.2 | 211.2 | 178.2 | 167.2 |
| Dec. 13..... | 37.4 | 103.4 | 206.8 | 187.0 | 193.1 |
| Dec. 21..... | 48.4 | 88.0 | 184.8 | 180.4 | 184.8 |
| Dec. 28..... | 50.4 | 105.6 | 167.2 | 162.8 | 178.2 |
| Jan. 10..... | 41.8 | 101.2 | 171.6 | 147.4 | 151.8 |
| Jan. 17..... | 37.4 | 77.0 | 149.6 | 158.4 | 136.4 |
| Jan. 28..... | 28.6 | 132.0 | 143.0 | 149.6 | 134.2 |
| Feb. 6..... | 35.2 | 74.8 | 160.6 | 116.6 | 110.0 |
| Totals .... | 449.6 | 1471.8 | 2145.0 | 2105.4 | 2083.4 |

The rate of oxidation, as measured by humus production and $CO_2$ production, follow the same order, namely, (1) maple leaves, (2) oak leaves, (3) pine needles, and (4) pine shavings. It should be noted that the shavings after having been in the soil for three or four months did not increase the percentage of humus; in fact, they lowered it slightly. The data are shown below.

| Material used. | Humus, percent. | Total $CO_2$, cg. |
|---|---|---|
| Soil alone .......................... | 2.96 | 44 |
| Soil + maple leaves ................. | 3.34 | 214 |
| Soil + oak leaves ................... | 3.18 | 210 |
| Soil + pine needles ................. | 3.07 | 208 |
| Soil + shavings ..................... | 2.91 | 147 |

### EXPERIMENT 4, CEREALS AND BUCKWHEAT.

Barley, oats, and buckwheat were used in this experiment because good samples of them were available. Barley and buckwheat are quite frequently plowed under as green-manure crops, which is not true of oats. Plants that were half matured were dried, ground, and mixed with the moist loam. The rate of oxidation is shown in Table 4. The data are also shown graphically in figure 45. Little or no consistent variation occurs. Buckwheat appears to be the most inert.

TABLE 4.—*Milligrams of $CO_2$ given off from untreated soil and from soil to which oats, barley, and buckwheat were added.*

| Date. | Loam 300 gr., untreated. | Loam 300 gr. + oats 15 gr. | Loam 300 gr. + buckwheat 15 gr. | Loam 300 gr. + barley 15 gr. |
|---|---|---|---|---|
| Nov. 15 | 35.2 | 349.8 | 442.2 | 428.8 |
| Nov. 22 | 33.0 | 338.8 | 283.8 | 380.6 |
| Nov. 29 | 50.0 | 242.0 | 176.0 | 341.0 |
| Dec. 6 | 52.0 | 239.8 | 182.6 | 281.6 |
| Dec. 13 | 37.4 | 176.0 | 184.8 | 191.4 |
| Dec. 21 | 48.4 | 253.0 | 138.6 | 195.8 |
| Dec. 28 | 50.6 | 184.8 | 125.4 | 176.0 |
| Jan. 10 | 41.8 | 189.2 | 162.8 | 138.6 |
| Jan. 17 | 37.4 | 176.0 | 160.6 | 134.2 |
| Jan. 28 | 28.6 | 184.8 | 158.4 | 118.8 |
| Feb. 6 | 35.2 | 147.4 | 136.4 | 123.0 |
| Totals | 449.6 | 2481.6 | 2151.6 | 2529.2 |

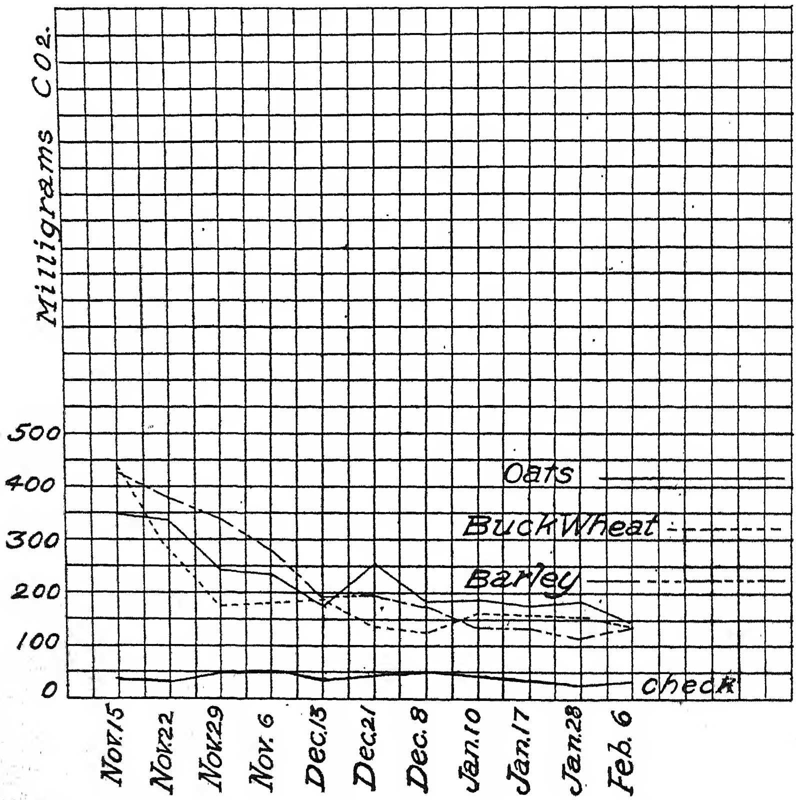


FIG. 45. Graph showing $CO_2$ given off during weekly periods from untreated soil and from soil to which oats, barley, and buckwheat were added. (Data from Table 4.)

The data on humus production of oats, barley, and buckwheat are as follows:

| Material. | Humus, percent. | Total $CO_2$, cg. |
|---|---|---|
| Soil alone | 2.96 | 44 |
| Soil + oat fodder | 3.18 | 248 |
| Soil + barley fodder | 3.10 | 252 |
| Soil + buckwheat fodder | 2.99 | 208 |

The humus production of oats and barley is very nearly the same, the variation being within the limits of error. Buckwheat seems to be a very inert substance, increasing the percentage of humus almost nil, while the total $CO_2$ given off in three months is considerably lower than than the other materials.

### GENERAL OBSERVATIONS.

Before the experiment was started it was expected that a wide variation in the rate of decomposition would be shown. Wollney (44) states that "Legume straws containing a high nitrogen content

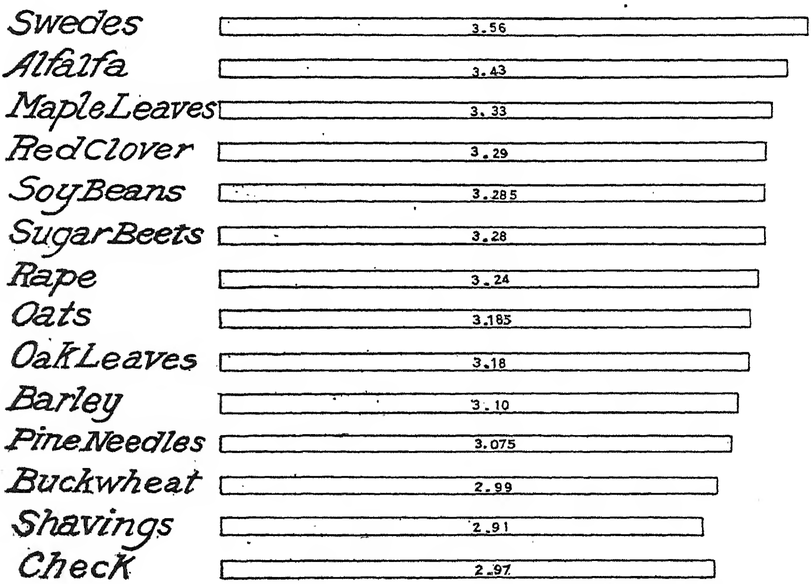


FIG. 46. Graph showing humus production from all materials used in the experiments.

are easily decomposed, grain straws are more resistant, while leaves and needles are still more so." The results show this to be true, but the difference is not as marked as might be expected. That white pine shavings should increase the $CO_2$ production as much as they did

is peculiar so it seems that the increased aeration afforded by the loose material has had some effect in causing a greater recovery of $CO_2$.

It should be remembered that all substances were dried before using, which may account for the uniformity of the results, although Lemmermann (21) found no difference between green and dry lucern. It would be nearly impossible to obtain, at the same time, all of the materials at the proper stage of growth and normal moisture content. To place everything on the same basis it seemed advisable to dry each in the same degree.

For the sake of comparison the humus production of all the materials is given in figure 46. It is believed that these results fairly represent the availability of the substances used.

### Action of Fertilizers on Decomposition.

A second series of experiments was run along the same period as those just cited in an effort to determine whether or not fertilizer materials increased the rate of decomposition. The same form of apparatus was used. Fifteen grams of soybean fodder and one gram of the fertilizer to be tried out were added to each flask. The results are shown in Table 5.

Table 5.—*Milligrams of $CO_2$ given off by soybean fodder to which various fertilizing materials had been added.*

| Date. | Soybeans alone. | Soybeans + sulfate of ammonia. | Soybeans + nitrate of soda. | Soybeans + ammonium phosphate. | Soybeans + calcium cyanamid. | Soybeans + acid phosphate. |
|---|---|---|---|---|---|---|
| Nov. 15 | 475.2 | 437.8 | 431.2 | 289.4 | 244.2 | 411.2 |
| Nov. 22 | 385.0 | 365.2 | 545.6 | 374.0 | 330.0 | 374.0 |
| Nov. 29 | 211.2 | 220.0 | 279.4 | 136.4 | 195.8 | 195.8 |
| Dec. 6 | 213.4 | 228.8 | 297.0 | 198.0 | 206.8 | 209.0 |
| Dec. 13 | 169.4 | 158.4 | 211.2 | 180.4 | 321.0 | 180.4 |
| Dec. 28 | 237.6 | 187.0 | 235.4 | 224.4 | 182.6 | 195.8 |
| Jan. 17 | 195.8 | 138.6 | 158.4 | 173.8 | 283.8 | 171.6 |
| Jan. 28 | 117.2 | 145.2 | 143.0 | 154.0 | 162.8 | 132.0 |
| Totals | 2054.8 | 1881.0 | 2301.2 | 1830.4 | 1927.0 | 1870.0 |

| Date. | Soybeans + raw bone; | Soybeans + basic slag. | Soybeans + sulfate of potash | Soybeans + kainit. | Soybeans + muriate of potash. |
|---|---|---|---|---|---|
| Nov. 15 | 296.0 | 413.6 | 446.6 | 352.0 | 407.0 |
| Nov. 22 | 341.0 | 389.4 | 409.2 | 255.2 | 191.4 |
| Nov. 29 | 228.8 | 193.6 | 209.2 | 224.4 | 204.6 |
| Dec. 6 | 209.0 | 283.8 | 184.0 | 202.4 | 204.6 |
| Dec. 13 | 169.4 | 259.0 | 191.4 | 158.4 | 136.4 |
| Dec. 28 | 220.0 | 242.1 | 217.8 | 228.8 | 171.6 |
| Jan. 17 | 167.2 | 187.0 | 147.4 | 167.2 | 134.2 |
| Jan. 28 | 156.2 | 173.8 | 154.0 | 112.2 | 112.2 |
| Totals | 1887.4 | 2141.4 | 1952.8 | 1700.6 | 1562.0 |

The results show that but two of the fertilizer materials tried out increase the rate of decay; these are nitrate of soda and basic slag. The others show but little effect with the exception of kainit and muriate of potash, which decrease the rate quite markedly. The results with kainit agree with the carbon balance experiments of Lemmermann, previously mentioned.

Calcium cyanamid contains carbon, so it is not fair to draw any conclusions regarding its effect on organic decay as measured by $CO_2$ production. However, it appears to be toxic to soil bacteria as is shown by the markedly lowered production during the first two weeks. This toxic action seems to last but one week, agreeing with the recommendations of Brooks, Schneidewand, and others that the material be applied a week or two before planting time.

More experimental work of this kind has been done with sulfate of ammonia than any other fertilizer and contradictory results have been obtained. Van Suchtelen, using a light application of sulfate of ammonia and measuring the $CO_2$ for a very short period (12 hours), obtained much more gas from the treated soil. Fred and Hart (10) made determinations at 2-day periods and, while an increase over the check is shown, it is not nearly as great as the above. Potter and Snyder (31) found a slight decrease in $CO_2$ production from the use of sulfate of ammonia, as did the writer. The results of the last two experiments are not entirely contradictory to the former, for the time factor enters. It seems that the immediate effect of the salt is to increase or stimulate bacterial action, but it is not lasting. The results obtained here, as well as those of Potter and Snyder, represent a length of time equivalent to a growing season and for that reason should be of more practical value.

The residues from the oxidation experiments were dried and their humus content determined. The results were as follows:

| Treatment. | Percentage of humus. |
|---|---|
| Soybeans 15 gr. alone | 3.285 |
| Soybeans 15 gr. + kainit, 1 gr. | 3.225 |
| Soybeans 15 gr. + raw ground bone, 1 gr. | 3.195 |
| Soybeans 15 gr. + muriate of potash, 1 gr. | 3.180 |
| Soybeans 15 gr. + sulfate of ammonia, 1 gr. | 3.175 |
| Soybeans 15 gr. + acid phosphate, 1 gr. | 3.155 |
| Soybeans 15 gr. + calcium cyanamid, 1 gr. | 3.130 |
| Soybeans 15 gr. + sulfate of potash, 1 gr. | 3.035 |
| Soybeans 15 gr. + ammonium phosphate, 1 gr. | 3.000 |
| Soybeans 15 gr. + rock phosphate, 1 gr. | 2.990 |
| Soybeans 15 gr. + basic slag, 1 gr. | 2.970 |
| Soybeans 15 gr. + nitrate of soda, 1 gr. | 2.865 |

Those materials which markedly depressed the production of $CO_2$, viz., kainit and muriate of potash, caused the least loss in humus. This is shown by the relatively high humus content in the jars treated with those substances. On the other hand the materials which increased the production of $CO_2$, viz., slag and nitrate of soda, have markedly lowered the humus content. Considering this one may infer that fertilizers act upon the soil humus and not upon the crude organic matter. One would expect the continued use of materials like nitrate of soda to cause a rapid depletion of the soil's humus content.

## Summary and Conclusions.

1. The legumes which are high in nitrogen show a more rapid rate of decay than straws and litters which are low in nitrogen. Nitrogen, then, seems to influence decomposition.

2. On farms where animal manures are not available the choice of green manures and cover crops is important. The results indicate that legumes would be most desirable on such farms.

3. Cyanamid appears to be toxic to soil bacteria, or at least arrests the decay of organic matter for two weeks after application.

4. Commercial fertilizers apparently act upon soil humus, decomposing it quite rapidly. They apparently do not act upon crude organic matter in the same way.

## Literature Cited.

Editor's Note.—The citations of literature as originally made by the author in the preparation of his thesis were not as complete as those usually printed in The Journal of the American Society of Agronomy, and unfortunately he is not now able to complete some of them. It is hoped that they will be sufficiently complete to be useful to the reader.


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## CROSS-POLLINATION OF SUGAR CANE.[1]

H. B. COWGILL.

Sugar cane has been propagated from seed and the seedlings selected for the purpose of originating new varieties since 1887. This was begun in Java and in Barbadoes at about the same time, and it has since been taken up in nearly all the cane-producing countries of the world. Originally no record was made of the parentage of the seedlings, and in many cases not even the name of the seed parent was kept. Some very good varieties were originated by this method.

For commercial purposes cane is propagated asexually by cuttings. When it is propagated from seed the variation in the resulting generation, even from a single parent variety, is considerable. It is presumed that some, if not all, of the varieties are more or less heterozygous. It seems nevertheless desirable, in many cases, to make controlled crosses in order to combine such characters as vigor and disease-resistance of certain varieties with good qualities of other varieties.

[1] Contribution from the Porto Rico Insular Experiment Station. Received for publication July 23, 1918.

### Methods of Crossing.

It would, of course, be desirable to eliminate all possibility of self-pollination. Attempts to emasculate the florets have been made, and a few seedlings have been produced in Barbadoes in that way; though, according to Bovell, the number of seedlings produced in any single season has been small. The work is very tedious, for the reason that the florets are small and the panicle is brittle. The latter is also produced at 10 to 15 feet from the ground, so that it is necessary to do the hybridizing on a scaffold and sometimes the wind makes the work very difficult.

Kobus (4),[2] in Java, planted a pollen-sterile variety on the leeward side of a pollen-fertile variety which flowered at the same time. Seeds of the former, when planted, grew and developed into canes which had characteristics of both parent varieties.

Another method reported by Bovell (1) to be employed in Barbadoes is to plant two varieties which flower at the same time in alternate stools, called the "checkerboard system," for the purpose of facilitating natural cross-pollination. It is of course impossible to form any conclusion as to the extent to which crossing takes place with this method, unless the type of seedlings produced by each variety when growing separately is known.

Two additional methods are described by Wilbrink and Ledeboer (6). By the first method the tassels of the variety to be used as the male parent are cut off and tied in position with the one to be used as a seed parent. For protection against undesired pollen a screen is provided, having an opening on the leeward side for the entrance of the tassels. By the second method the pollen of the desired variety is collected and carried to the one to be used as the female parent. This later method is also one which was suggested by D'Albuquerque (3). It is reported that the pollen adheres in masses, and also soon deteriorates, so that no very satisfactory results were obtained.

### Methods Employed at the Insular Experiment Station.

Crossing has been practiced at the Insular Experiment Station of Porto Rico for four years. The method here described was found to be more suitable, for the reason that with its use a fairly large number of seedlings can be produced. The work has not yet progressed far enough to report results of the crossing, in respect to the quality of varieties produced. It has been possible, however, to study to some extent the populations of seedlings originating from different

[2] Figures in parentheses refer to "Literature cited," p. 306.

parentages, as to inheritance of characters in first-generation seedlings.

Bags made of cheese-cloth are held extended by heavy wire rings sewed into them. The bags when completed are 48 inches long and 18 inches in diameter. The rings are placed one at the top and the other 16 inches from the bottom, so that a skirt of 16 inches is left to be drawn in and tied around the stems of the panicles.

The bags are supported over the panicles by means of bamboo poles set in the ground. The poles have a crossbar at the top which is fastened to them by being wedged into notches cut into the second internode from the top, and the bags are tied to this crossbar. The poles are set on the windward side of the stools just before the panicles "shoot;" when this occurs, a bag is immediately suspended over each panicle and tied around its stem, so that it is protected from all undesired pollen before any of the florets open.

The cane blossom is hermaphrodite, but it has been found that certain varieties are almost completely pollen-sterile, or at least self-sterile. This makes it possible to pollinate them with another variety, with the assurance that nearly all the seedlings will be offspring of two known parent varieties, a few usually also being produced as the result of the self-pollination of the mother parent.

The pollinating is done by placing panicles of the desired variety into the bag, in such a position that their pollen will be shed or carried by the wind to the florets of the other variety as they open. One or two panicles are used at a time, and they are allowed to remain in the bag two or three days, being renewed as often as necessary while the florets are opening. It has been found of advantage to cut the panicles with stems 4 to 6 feet long, and to place their lower ends in a joint of bamboo filled with water, by which they can be kept fresh two or three days.

### Results Accomplished.

Up to the present time, results can only be expressed in terms of the number of seedlings produced and the extent to which the characters of the varieties are combined. The method above described was first tried in 1915–16. Ten crosses were attempted, of a single combination, and all but two produced seedlings, a majority of which, when mature, showed characteristics of both parents. In all, about 1,600 seedlings were produced, one panicle alone giving over 1,000 seedlings (2).

In the following winter of 1916–1917, thirty crosses, comprising nine different combinations, were attempted, and nineteen of them,

comprising six combinations, were successful. From one combination 1,309 seedlings were obtained, and in all 2,589 seedlings were produced. The work was all done by one man and a helper, including the making of the bags.

In 1917–1918 it was impossible to secure the services of a competent man to perform the crossing until late in the season, and the seed of all varieties was also much less viable than in the preceding year. Thirty crosses were attempted, comprising nine combinations. Fifteen of these were successful and 1,794 seedlings were produced, 857 of which were from one combination and 735 from another.

Judging from the small proportion of the seedlings out of the large number propagated by the old method that are of sufficient value to become widely cultivated, it appears that a large number of first-generation seedlings is essential. Considered from the point of view of Mendelian inheritance, if many factors are involved, which is probably the case, the chance of getting a desired combination of characters is very remote when only a few seedlings are grown.

### Effect of the Crossing.

In 1915–1916 the variety used as a pollinator was a dark-colored cane, while the seed parent was medium light. This made it possible to trace the color of the male parent in the offspring. Some other characters could also be traced in the seedlings in the same way. In the following year this cross was again made, and the same general effects were observed, many of the same types being again recognized (2).

In the year 1916–1917, some of the parent varieties of groups of seedlings showed fewer differences than was the case with the varieties combined the year before, consequently it was less easy to see the effect of the crossing in the seedlings. In all cases but one, however, some of the groups showed distinguishing characteristics of both parent varieties.

The disadvantage in this method, in not being able to eliminate all possibility of self-pollination, ought not to be overlooked. On account of the chance of some selfing, it has been the practice to estimate the value of a cross from the entire group of seedlings produced, always making allowance for probable self-pollination.

### Self-Sterility.

At least two of the old standard varieties are nearly pollen-sterile here. We have never succeeded in producing more than one to five

seedlings from single flats of several hundred seeds planted, while if these same varieties are pollinated by any of several seedling varieties good germination follows. Lewton-Brain (5) in Barbadoes examined the florets of about fifty varieties and found that some bore pollen nearly all of which was large, well-shaped and full of dark granules, while with some the pollen was smaller, more or less irregular in form, and without granular matter. A third class of varieties had an intermediate amount of normal, well-developed pollen.

Wilbrink and Ledeboer (6) describe a method of testing the pollen with iodine, to determine its viabilty. If the pollen grain contains starch it was believed to be normal. We have not, however, found this test to be absolutely reliable.

## Conclusions.

From the work reviewed in the foregoing paper the following conclusions are possible:

1. Sugar cane can be cross-pollinated and protected from outside pollen, and by this process a considerable number of seedlings can be produced.

2. Characters of the parent varieties are combined in the seedling by this process.[3]

[3]It should be expected that the desirable combinations could be perpetuated in hybrid condition because of the asexual method of propagation, a rather unusual advantage among our field crop plants. (Editorial note by L. H. Smith.)

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# AGRONOMIC AFFAIRS.

## ANNUAL MEETING IN BALTIMORE.

The eleventh annual meeting of the American Society of Agronomy will be held in Baltimore, Md., November 11 and 12. The call for papers for the program has been sent out by the Secretary. All who expect to present material at this meeting are urged to send titles at once to Lyman Carrier, Department of Agriculture, Washington, D. C.

## ERROR IN THE JANUARY NUMBER.

The editor's attention has been called to an error which occurred in the article by Dr. George F. Freeman in the January issue of the Journal. In Table 2, page 25, the words "hard" and "soft" are transposed throughout, so that the data are made to show just the opposite tendency from that actually indicated. All readers are requested to change the column headings in this table as here indicated.

## MEMBERSHIP CHANGES.

The membership reported in the September issue of the Journal was 652. Since that time 9 new members have been added and 10 have resigned, making the present membership 651. Names and addresses of new members, names of members resigned, and changes of address which have been reported follow.

### New Members.

Birchard, J. F., Cor. Magnus Ave. and Main St., Winnipeg, Manitoba.
Blackwell, C. P., Clemson College, S. C.
Damon, S. C., Agr. Expt. Sta., Kingston, R. I.
Elliott, B. S. A., School of Agr., Olds, Alta., Canada.
Fergus, E. N., Agr. Expt. Sta., La Fayette, Ind.
Grisdale, F. S., School of Agr., Vermilion, Alta., Canada.
Monteaguda, Heriberto, Quinta de los Molinos, Habana, Cuba.
Stephen, W. J., School of Agr., Claresholm, Alta., Canada.
Van Schaik, K. L., Pretoria, Transvaal, South Africa.

### Members Resigned.

Davisson, B. S.,
Deeter, E. B.,
Gray, Wm. F.,
Hitchcock, E. B.,
Lyness, W. E.,
Northrop, Robt. S.,
Sherbakoff, C. D.,
Sleeth, E. C.,
Young, Horace J.,
Zahnley, J. W.

### Changes of Address.

Alexander, L. L., State Normal School, Springfield, Mo.
Bauer, F. C., 218 N. Lake St., Madison, Wis.
Beavers, J. C., Guilford College, N. C.
Bugby, M. O., Kingsville, Ohio.
Farrell, F. D., Agr. Expt. Sta., Manhattan, Kans.
Frear, D. W., Crop Estimates, U. S. Dept. Agr., Washington, D. C.
Freeman, Geo. F., Societe Sultanienne d'Agriculture, Cairo, Egypt.
Gernert, W. B., Farm Bureau, Paris, Ill.
Goddard, L. H., Washington Ave., Washington C. H., Ohio.
Jensen, L. N., Box 308, Big Springs, Tex.
Lund, Viggo, Tystoftu Expt. Sta., Tjaereby, Denmark.
Menzies, E. C., Aylesburg, Sask., Canada.
Miner, Sterling L., 1029 Sixth St., Greeley, Colo.
Petry, E. J., 210 South Ingalls St., Ann Arbor, Mich.
Southwick, Benj. G., Mass. Agr. College, Amherst, Mass.
Stadler, L. J., 410 South Maple St., St. Louis, Mo.
Thatcher, Lloyd E., Ohio Agr. Expt. Sta., Wooster, Ohio.
Tillman, B. W., Univ. of Mo., Columbia, Mo.
Walster, H. L., Soils Bldg., College of Agriculture, Madison, Wis.

## ROLL OF HONOR.

The Society's roll of honor of men in military service now contains the names of 47 men. No doubt there are many others whose names have not been reported to the officers of the Society. The editor will appreciate information regarding men in the service of their country, both items of news and lists of names of men from various institutons who are now engaged in war activities. The names of those who have been reported to the editor follow.

Albert, A. R.,
Andrews, Myron E.,
Bliss, S. W.,
Brockson, W. I.,
Bruce, O. C.,
Brunson, A. M.,
Burnett, Grover,
Cates, Henry R.,
Chapman, James E.,
Childs, R. R.,
Deatrick, E. P.,
de Werff, H. A.,
Dickenson, R. W.,
Downs, E. E.,
Ellison, A. D.,
Freeman, Ray,
Gentle, G. E.,
Gilbert, M. B.,
Graham, E. E.,
Gray, Samuel D.,
Hanson, Lewis P.,
Holland, B. B.,
Hudelson, R. R.,
Jensen, O. F.,
Kenworthy, Chester,
Kime, P. H.,
Macfarlane, Wallace,
Moomaw, Leroy,
Newton, Robert,
Palmer, H. Wayne,
Piemeisel, R. L.,
Purington, James A.,
Quigley, J. V.,
Ratcliffe, Geo. T.,
Raymond, L. C.,
Richards, Phil E.,
Schneiderhan, F. J.,
Schoonover, W. R.,
Scott, Herschel,
Smith, J. B.,
Spencer, E. L.,
Stanley, C. W.,
Starr, S. H.,
Tabor, Paul,
Towle, R. S.,
Ware, J. O.,
Westbrook, E. C.

## NOTES AND NEWS.

E. C. Chilcott, C. S. Scofield, and T. H. Kearney of the Department of Agriculture are now in Algeria, Tunis, and Morocco, where they are investigating the possibilities of increasing the agricultural output of these French colonies. The trip is being made at the request of the French high commission to the United States.

G. I. Christie, director of extension in Indiana and for the past several months assistant to the secretary of agriculture, has been named as assistant secretary, succeeding R. A. Pearson, resigned to resume his duties as president of Iowa State College.

G. H. Collings has been appointed assistant professor of agronomy and assistant agronomist at the Clemson (S. C.) college and station.

George F. Freeman, plant breeder of the Arizona station, has resigned to take up cotton-breeding and cultural work for the Egyptian Government in the valley of the Nile.

Ben C. Helmick, formerly assistant professor of agronomy in the Minnesota college of agriculture, is now instructor in agronomy in the Connecticut college and associate agronomist of the Storrs station.

C. G. Hopkins has been granted a year's leave of absence from the Illinois college and station to head the agricultural section of the Red Cross commission to Greece. He will study soil conditions, particularly with a view to the quick and permanent increase in food production. He will be assisted by George Bouyoucos of the Michigan station, the son of a Greek farmer, who has had fifteen years training and experience in this country.

W. L. Hutchinson, for the past several years professor of agronomy at Clemson College, has resigned and has been succeeded by C. P. Blackwell, who will also be agronomist of the South Carolina station.

J. S. Jones, formerly director and chemist of the Idaho station, has resigned to take charge of the operating laboratory of one of the Government's nitrate plants under the ordnance division of the War Department.

F. M. Rast, jr., formerly assistant professor of soils and fertilizers in the University of Florida, has been appointed assistant professor of agronomy in the Delaware college, succeeding M. L. Nichols, who is now in charge of extension work in farm engineering in Virginia.

Benjamin G. Southwick, formerly of the Connecticut college, is now demonstrator in farm management in the Massachusetts college.

J. L. Staden and C. C. Hearne have been appointed assistants in farm crops in the University of Missouri.

L. E. Thatcher has resigned as instructor in farm crops in Ohio State University and is now assistant agronomist in charge of plant-breeding work at the Ohio station.

B. W. Tillman, formerly of the soil survey force of the Federal Department of Agriculture, has resigned to become extension assistant professor of soils in Missouri.

H. L. Walster, who has been pursuing graduate study in plant physiology and ecology at the University of Chicago, has returned to his work at the University of Wisconsin, having received the Ph.D. degree at the August convocation. He will devote most of his time in Wisconsin to plant nutrition studies.

A committee to obtain information on food production conditions in Great Britain, France, and Italy, with a view to making these conditions known to agricultural leaders and to farmers generally in this country and to enable us to render aid more effectively to these countries, arrived in England September 1. The committee consists of Dr. W. O. Thompson, president of Ohio State University, chairman; Carl Vrooman, assistant secretary of agriculture; R. A. Pearson, president of Iowa State College; T. F. Hunt, director of the California station; D. R. Coker, farmer and member of the national agricultural advisory committee; W. A. Taylor, chief of the Bureau of Plant Industry; G. M. Rommel, of the Bureau of Animal Industry; and George R. Argo and John F. Wilmeth, of the Bureau of Markets.

Probably for the first time in history, the Federal Government has been making direct loans to farmers to finance fall seeding of wheat and rye. These loans are being made in Montana, North Dakota, Kansas, Oklahoma, and Texas, where crop failures during the past two years have been general over wide areas. Only those who can obtain funds in no other way are being financed. The work is under the joint supervision of the Treasury and Agricultural departments, the applications being approved by the Department of Agriculture and the loans completed by the Treasury Department, through the Federal land banks in these districts. G. I. Christie, assistant to the secretary of agriculture, has been in charge of the work in the northern district and L. M. Estabrook, chief of the bureau of crop estimates, has supervised the making of loans in the southwest. C. W. Warburton and H. N. Vinall have been chief assistants to Messrs. Christie and Estabrook, respectively. The loans are being made from the President's war emergency fund, $5,000,000 having been set aside for that purpose. The portion of the fund not loaned this fall will be used for financing seeding of spring wheat.

## Third Western Agronomic Conference.

Agronomic workers in the eleven western states met in the third western agronomic conference at Corvallis, Oreg., July 23, 24, and 25, 1918. The meetings were attended by more than forty agronomic workers representing the various State experiment stations, agricultural colleges, and extension departments, the United States Department of Agriculture, and the British Columbia Department of Agriculture.

Roland McKee of the Office of Forage Crop Investigations, U. S. Department of Agriculture, stationed at Chico, Cal., discussed experimental methods for establishing forage standards. He emphasized the importance of basing forage yields on the oven-dry basis because of varying rates of loss of moisture after cutting with different varieties, and also with light and heavy yields of the same variety. H. A. Schoth of the same office, stationed at Corvallis, Oreg., discussed production problems in connection with forage-crop experiments.

Experimental work in the prevention of smut explosions and in grain cleaning in the smut-infested areas of the Northwest, as well as means of collecting smut spores to prevent soil infection, was presented by C. C. Ruth, of the Portland grain supervision office, Bureau of Markets. H. P. Barss, professor of botany and plant pathology of the Oregon college, discussed the smut and rust control work under way in the United States and the splendid results accomplished by the pooling of interests of the plant pathologists throughout the country.

R. L. Stewart of the New Mexico college presented a very interesting paper on the utilization of soaproot and sotol as forage for range cattle. He stated that thousands of head of cattle had been carried through the period of forage shortage by feeding these plants finely chopped. Range management in Wyoming was discussed by A. F. Vass, agronomist of the Wyoming station. He showed the direct relation between dry years and loss of stock and also the relation between prices and the rise and decline of the stock population of the State.

O. E. Barbee of the Washington station presented a season's data on the influence of date of seeding on winter wheat. Row versus plat plantings for varietal tests of cereals were discussed by D. E. Stephens, superintendent of the Moro, Oreg., substation. Reliable results have been obtained at this station from row tests.

J. A. Clark, agronomist in charge of western wheat investigations for the U. S. Department of Agriculture, presented the scheme of classification of wheat varieties worked out by C. R. Ball and himself, and then illustrated the scheme by taking the visiting agronomists to the wheat nursery of the Oregon station, where the various commercial varieties of wheat of the United States were being grown.

Soil problems in the Palouse district, particularly with reference to humus and nitrogen, were discussed by F. J. Sievers of the Washington college. Experimental work with alkali soils in Utah was presented by B. W. Pittman, and soil survey problems in Oregon and Idaho were discussed by C. V. Ruzek and E. B. Hitchcock, respectively. The follow-up work after the mapping and physical classification were completed was stated to be of maximum importance.

W. L. Powers of the Oregon college presented a paper on some phases of experimental work in farm management, and George Stewart of the Utah college talked of irrigation investigations being conducted in that State. The results of an extensive survey of problems of the field-pea growers of Idaho were presented by H. W. Hulbert.

A round-table discussion on the bulk handling of grain in the Pacific Northwest was led by A. L. Rush of the Bureau of Markets and G. R. Hyslop of the Oregon college and was participated in by many of those present. The discussion of factors affecting quality of wheat was introduced by J. W. Gilmore of the University of California. It was agreed by those present that quality of wheat was dependent on both soil and climatic conditions.

H. D. Scudder, professor of farm management in the Oregon college, presented plans for land colonization in Oregon, particularly with reference to a model farm colonization unit.

Farm crops work offered in the various western colleges was presented in tabular form and discussed by E. G. Schafer of the Washington college, particularly with regard to its relation to other required work. Agronomic extension work was discussed by Leonard Hegnauer and R. J. Leth, extension specialists in agronomy in Washington and Idaho, respectively. The importance of extension correspondence was particularly emphasized.

The invitation of Professor Gilmore to hold the 1919 conference in Berkeley was accepted, and the date of the meeting was set for early June. Professor Gilmore was elected chairman of the 1919 conference, and named Roland McKee and G. R. Hyslop as additional members of the committee on arrangements. As some of the agronomic meetings in the Middle West have now been abandoned, it is hoped that agronomists from that section will join with western agronomists in the 1919 conference at Berkeley.

G. R. Hyslop, *Secretary.*

# JOURNAL

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## INFLUENCE OF HIGHER PLANTS ON BACTERIAL ACTIVITIES IN SOILS.[1]


T. LYTTLETON LYON.


In considering the relation of plants to soils attention has in general been more concerned with the effect of the soil on the plant than with the influence which the plant may exert on the soil. When, however, the latter has received consideration it has been mainly from the standpoint of the quantity of fertility removed. In more recent years investigations have been conducted to ascertain the effects of green-manuring crops or of systems of crop rotations on nitrogen transformations in soils.

The subject to which I wish to call your attention is the immediate influence of the growing plant on certain bacterial processes in the soil, a subject which has a bearing on the practical problems of crop production and which is now in that interesting stage of suggestion that is so alluring to the investigator.

The literature of soil investigation is not rich in indications that the bacterial flora and its activities are influenced by growing plants, but some such suggestions may be found, and they give a reasonable basis for encouraging further investigations. I shall not attempt an exhaustive review of this literature, but shall mention some of the work that appears most significant. I find only a few investigations that attempt any correlation between the growing plant and the bacterial flora. One is a piece of work by Hoffmann in which he counted the number of bacteria in soil immediately adjacent to plant roots and

[1] Presidential address before the eleventh annual meeting of the American Society of Agronomy, January 6, 1919. Read by C. E. Leighty in the absence of President Lyon.

at some distance away. He examined a large number of plants of different genera and species and found almost uniformly a denser flora near the roots. He is also supported by Stoklasa, who found under different crops marked differences in the germ content of the soil. It will, of course, require a very considerable number of tests to establish the certainty that roots of growing plants improve the surrounding soil for the development of bacteria and that certain higher plants are more effective than others in this respect. It is mentioned here, however, because the possibility is suggested rather strongly.

A class of microorganisms whose activities, there is reason to believe, are influenced by growing crops is that portion of the flora which reduces nitrates to less highly oxidized forms of nitrogen. An unaccountable disappearance of nitrates from soils on which crops were growing has been noted by several investigators. A number of explanations have been proposed. Dehérain attributes it to the drying out of the soil by the growing plants during the season most favorable for nitrification. Warington thought that it might be due to denitrification with loss of nitrogen into the air and possibly to loss of nitrogen from the plant. Russell merely states that it indicates a diminished production of nitrates and Leather is inclined to accept the explanation which will be given later.

A typical example of this disappearance of nitrates may be found in the lysimeter experiments of Dehérain in France, Leather in India, and of the Cornell experiment station. In all of these experiments certain plants grown in lysimeters from which both the plants and drainage water were analyzed gave as a balance at the end of the experiment less nitrogen in the crop plus the drainage water of the planted soil than in the drainage water alone of the soil on which no plants grew. No analyses having been made of the soil it is uncertain what finally became of the nitrogen that failed to appear either in the crop or in the drainage water.

It is evident that the problem must be attacked in a different way and to do this plants were grown in nutrient solutions which were kept sterile through the entire period of the growth of the plants, amounting in some cases to nearly a year. In these solutions contained in 12-liter flasks plants were grown to maturity and maize reached a height of 6 feet. The solution being sterile when the plant was harvested, it could be used as a medium in which to conduct bacterial transformations of nitrogen with pure cultures. To study the possible disappearance of nitrate nitrogen the solution in which the plant had grown had added to it a definite quantity of a nitrate salt

and, after inoculation with a nitrate-reducing organism, it was incubated and the quantity of nitrate that disappeared in a certain time was ascertained by analysis. This was compared with a similar nutrient solution in which no plant had grown. Without taking the time that would be consumed in presenting the figures involved in this and other experimental work described in this paper I may say that there appeared to be a markedly more rapid reduction of nitrates in the solution in which the plant had grown than in the other, the experiment being repeated many times.

The composition of the nutrient solution in which the plant had grown and the one in which it had not was, of course, different on account of the removal of certain substances by the plant. To make the two as nearly similar as possible 10 c.c. of the solution in which the plant had grown was added to 90 c.c. of another medium. The same was done with the solution in which no plant had grown and under these conditions the solution in which the plant grew increased the rate of nitrate reduction more than did the solution in which no plant grew. Analyses of the solutions after incubation showed that part of the nitrates had been converted into organic forms.

Infusions of macerated plant roots were made and reduction of nitrates tested in solutions to which these were added. It was found that such infusions increased nitrate reduction and that the more infusion added the more rapid was the disappearance of nitrate. Mannite was used in the incubated solutions as a source of energy for the bacteria and it was found that within certain limits an increase in the quantity of mannite served to hasten nitrate formation. The organic matter available to the reducing organisms is doubtless a factor in determining their activity.

In solutions in which plants grew as well as in media to which infusion of macerated roots was added it was attempted to ascertain whether nitrate reduction went on in the presence of an antiseptic, phenol being used. Such reduction did occur while it did not do so in check solutions, but it was slight and the evidence indicates that the effect of growing plants on nitrate reduction is due only in part to enzymotic action. Reducing enzymes were generally found, however, in plant solutions and in root infusions. Oxidates were sometimes shown to be present in plants growing in agar, timothy roots always giving reaction for these. Reactions for peroxidases were always obtained in agar near the roots of all plants tested. Boiling the solutions before inoculation lessened nitrate reduction, thus indicating that enzymes or some similar substances played a part in the process.

The experiments that have been described indicate two possible ways in which higher plants may influence bacterial activities in soils. One of these is through the result of plant growth on the composition of the soil solution. Experiments by a number of investigators show that the relative quantities of certain anions and cations in solution may influence the rate of the nitrifying process. The presence or absence of organic matter has also been shown to be a factor.

The experiments that have been mentioned indicate that both of these conditions may influence reduction of nitrates. The growing plant may be expected to have an influence on the composition of the soil solution. From the time that the plant begins to grow until it reaches the stage of full bloom it is absorbing nutrients from the soil solution with slight if any return to the soil. During this period there is doubtless a decrease in the concentration of the soil solution, as absorption apparently proceeds faster than solution. After the stage of full bloom a marked diminution in the absorption of the solutes begins. A change in the composition of the soil solution may be looked for during the later stages of growth of the plant. It is during the middle and later stages of growth that the reduction of nitrates appears to be most marked. Plants of different kinds also differ in respect to the quantities and rates of nutrients absorbed and may thus be expected to exert different effects on the rate of reduction of nitrates.

Another possibility is that the organic matter in the soil solution is more or less influenced by plant growth and that this organic matter affects the activities of the bacteria that bring about the transformations of nitrogen. The organic matter in solution constitutes a very small part of the total organic matter of the soil. Being in solution it is in a condition to affect bacterial activity. In the experiments previously mentioned there was found in the solutions in which plants had grown a half percent as much organic nitrogen as was found in the plant at maturity, altho these solutions were originally composed only of inorganic substances. This organic matter given off by the plant roots may conceivably be a factor in the depressing effect on the nitrate content of soils.

In trying to determine the action of any plant on transformations of nitrogen little can be learned by making incubation tests of the soil placed in flasks. The aeration and partial drying which the soil undergoes in the process is likely to nullify any effect which the crop may have had. It is well known that either complete or partial drying

of a soil results in materially increasing its solubility. Any effect that the plant may have exerted on the composition of the soil solution would therefore be changed and nitrogen transformations may be very different from what they would have been in the untouched soil. Even the operation of plowing causes a change in the rate of nitrate formation, as has been shown by Brown and MacIntire. The best way to determine the ultimate effect of a crop on nitrate formation is to remove the crop and allow the soil to incubate without disturbing it, at the same time maintaining an optimum moisture content.

Another bacterial process in soils which appears to be influenced by some higher plants is the production of carbon dioxide. Under certain conditions the carbon-dioxide content of the air of soil on which plants had matured was lower than that of soil on which no plants had grown, altho the opposite was the case during the time the plants were making their greatest growth. Both nitrate production and carbon-dioxide formation are associated with the decomposition of organic matter and it would thus appear that this process is in a measure at least controlled by crop growth.

Not only does there appear to be a depression of nitrate production by certain higher plants, but other of these plants seem to have a stimulating influence on the formation of nitrates. This, however, appears to be exerted only during the early stages of growth. There is not so much evidence regarding this property of plants as there is regarding their depressive action, but there is some indirect experimental indication of its occurrence.

Fraps found that 50 to 100 percent more nitrogen was removed from the soil by maize plants in the first nine weeks of their growth than was apparently transformed from organic compounds into ammonium and nitrate salts during the same time.

The figures given by Stewart and Greaves in a study of nitrates in irrigated soils planted to maize, potatoes, and alfalfa, and also on land fallowed during a period of three years and planted to oats one year, show nitrates to be higher under maize at certain stages in the growth of the crop than in fallow land. The same was true of potatoes in their later experiments.

Results reported by Jensen showed that soil planted to maize contained more nitrates during the first part of July than did fallow land.

Bower determined nitrates in soil of unplanted plots both cultivated and uncultivated, and in maize plots cultivated and uncultivated. In both cultivated and uncultivated plots nitrates under the maize were higher during July than in the bare soil.

Similar results have been obtained in our experiments in the field and also in lysimeters. In the lysimeter experiments records were kept of the quantity of nitrogen removed annually in the drainage waters and in the crops, the period for the calculations beginning May 1 and closing April 30 following. This covers the period during which the crop is on the soil and the interval before the next planting, during which time conditions are favorable for leaching out the nitrates that may have accumulated in the soil during the summer. Comparing the quantities of nitrogen thus removed in the drainage water of unplanted soil with the nitrogen in the crop plus that in the drainage water of planted soil we found that for maize the total quantity of nitrogen removed in the crop and drainage was considerably greater than from the unplanted soil. From oat soil slightly more nitrogen was removed than from bare soil, but from soil growing timothy and other true grasses less nitrogen was so removed.

Taken as a whole these experiments indicate that with maize there is a stimulating influence on nitrate formation which is more potent than the depressing influence, while with timothy the opposite is the case. Oats appear to be intermediate between maize and timothy in their influence on nitrate formation and it is doubtful whether the stimulating or depressing effect is greater.

Laboratory experiments in which methods were employed similar to those used to test the activities of nitrate-reducing bacteria were conducted with ammonifying bacteria. These gave some slight indication that the solutions in which plants had grown produced somewhat more ammonia from peptone than did similar solutions in which no plants had grown. Owing to the difficulty in getting pure cultures of nitrate-forming organisms the influence of plants on formation of nitrates has not been tried with these methods.

Decomposition of organic matter is commonly and doubtless properly regarded as one of the most important factors in rendering a soil fertile. If a crop can stimulate or retard this process at certain stages of its growth it holds the key that locks or unlocks the supply of plant nutrients for its own use and possibly influences to some extent the supply for the crops that follow. It has long been held that plants possess the power of rendering available for their own use the food materials contained in soils. The idea was advanced by Sachs that plant roots excrete organic acids which act on the inorganic matter of soils, dissolving a part of that which comes in immediate contact with the root hairs and thus rendering it suitable for absorption. That organic acids other than carbonic are excreted by plant roots was discredited by the investigations of Czapek and there are few scien-

tists who still believe that plants secure nutrients by such a process. The fact still remains that some plants apparently obtain more of certain inorganic substances from soils than would appear to be possible from their solubility in water. Certain other plants obtain much smaller quantities of these nutrients. The influence which these plants exert on the decomposition processes in the soil may be a factor in determining whether they obtain much or little nutriment.

Clover and alfalfa also appear to have a marked effect on bacterial activity in soils. It has, of course, been known from an early time that plants of this class increase the productivity of a soil both when plowed under and when raised for hay. The discovery some 30 years ago of the symbiotic relation of nitrogen-fixing bacteria and leguminous plants apparently explained in full the reason for their usefulness in promoting soil fertility. Since the growth of legumes on properly inoculated soil results in fixation of atmospheric nitrogen and therefore in an increase in the quantity of nitrogen in a soil the conclusion naturally follows that the resulting improvement in crop production is due to the increased supply of nitrogen that follows the growth of legumes.

If, however, it is found that the growth of a legume has not increased the nitrogen content of a soil and yet that the productivity of that soil has been augmented, how then are we to account for the effect of the legume? An examination of the data at hand calls for the formulation of a different explanation.

That the growth of a legume is not always accompanied by a greater accumulation of nitrogen in the soil than is the growth of certain native prairie grasses has been strikingly brought out by Swanson, who determined the nitrogen content of a large number of soils in the state of Kansas. Half of the samples were from alfalfa fields of from 20 to 30 years standing and the remainder had been in native grass pastures. In each case the alfalfa field and the pasture were near together and apparently of the same soil type. His results show that the alfalfa did not leave the soil any richer in nitrogen than did the other cropping treatment. Somewhat similar results were obtained by Alway and Bishop with soil from a clover field and a contiguous one in nonleguminous crops.

At the Cornell experiment station four adjoining plots of land, two of which had been in timothy for six years and two in alfalfa for the same length of time, were carefully sampled and the nitrogen content of the soil determined. There was no difference between the timothy and alfalfa soil on one section and only 0.01 percent on the other. When these were plowed and planted to maize the alfalfa soil pro-

applied to soils on which lime is needed apparently increases the benefit to the nonlegume as does also the application of suitable fertilizer.

The subject which I have outlined in a superficial way touches many aspects of crop production. Its study, however, is difficult. The complex nature of the soil and the rapid chemical and biological changes that occur when a soil sample is removed from the field or vessels in which plants are grown may entirely mask the effects produced by plants. New methods must be devised and great patience must be exercised in the investigation of this subject. It is nevertheless one of the problems that must be solved if we are to have the fundamental knowledge on which to base a rational system of crop management.

## THE PREPARATION OF MANUSCRIPTS FOR PUBLICATION.

C. W. Warburton.

The preparation of manuscripts for publication in the Journal of the American Society of Agronomy or elsewhere deserves more than passing attention. If material is worth presenting at all, it is worth presenting in the best possible form. Carelessness or haste in the preparation of a paper often results in its rejection, even tho the matter it contains is otherwise worthy of publication. A poorly prepared paper, if published, is unsatisfactory to the writer and to the reader, unless the editor devotes much time to its revision.

Clearness and accuracy of expression are of major importance. Naturally, not all men have the same ability to present facts in clear, concise language, but all can strive to obtain clarity of expression. Fine writing should be avoided. A short word is far better than a long one if it conveys the same idea quite as effectively. If six words can be made to do the work of ten, the omission of the useless verbiage is a distinct gain. To quote George Otis Smith:[1] "The . . . scientist has at least two obligations: First, that of making his investigations more and more exact in method and direct in result; second, that of making his product, the written report, such as to meet the needs of not only his professional associates but also the general public."

It is not the intention, however, to make this brief note a discussion of style, but rather one of form. Articles concerned with instruc-

[1] Smith, George Otis. Plain writing. *In* Science, n. s., 42: 630–632. 1915.

tion, demonstration, experimentation, or research in agronomy will be accepted for publication in this journal. They may be reports of the results of original research, or they may be reviews of the work of others. Reviews of literature, however, should be critical digests of the available material on a subject rather than mere lists of titles. It is understood that articles submitted for publication have not been published previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the editor of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY. Papers varying in length from 1 to 32 pages are acceptable; short papers will in general be given preference.

*Form of Manuscript.* Articles for publication should be typewritten on sheets approximately 7 by 11 inches in size. Carbon copies are not acceptable, as they are often blurred and are frequent sources of error, particularly in tabular matter. A duplicate copy should be retained by the author. Text pages should be double or triple spaced, preferably the latter, with wide margins. If the body of the text is triple spaced, double spacing may be used for quotations, citations, etc. Single spacing allows no opportunity for editorial changes and should never be used. The principal sections of the article should be indicated by subheadings, the relative rank of the subheadings being shown by underscoring or other means. Every page of a manuscript, including tables, should be numbered consecutively.

*Illustrations.* Only such illustrations as are distinct additions to the text and aid in a clear understanding of it are acceptable. Each illustration must be specifically referred to in the text. Line drawings (text figures) are preferable to photographs, which require the making of half-tone engravings and printing on separate plates. Text figures should be numbered consecutively in the order of their occurrence, using Arabic numerals. Always refer to illustrations by number, as "figure 12," not "the following figure." If a distinct portion of a figure is referred to, it should be indicated by a capital letter in the text reference and also in the drawing itself, as "figure 14A." Text figures should be drawn in India ink on white or tracing paper, though the use of cross-section paper is permissible if it can not be avoided. All lettering should be clear and distinct. Each figure should be accompanied by a brief descriptive legend, plainly written.

Photographs, when essential for use as illustrations, will be reproduced as plates. Ordinarily two illustrations are reproduced on a single plate. Reference to plates should be by number, as "Plate 2, figure 1." Photographs for reproduction should be clear, black and white glossy prints. They should be unmounted, but should be

attached slightly at the corners to a sheet of paper of the same size as the text of the manuscript. This sheet should bear the plate and figure numbers and a short descriptive legend.

*Tabular Matter.* No other feature of editing occasions so much labor as the putting of tabular matter in form for publication. All table legends should be clear, concise, descriptive statements of the matter in the table. Tables should be numbered consecutively in Arabic numerals, and references to tables should always be by number, as "Table 4," not "the following table." Arrange the data in the most compact form which will present clearly the information desired. Each column heading should indicate the nature of the data in that column. The unit of measure should be expressed in the legend if all data in the table are in the same unit, as "Dry weight in grams of crops grown, etc." If more than one unit is used, the unit for each column should be specified at the top of that column.

Tables preferably should be written on separate sheets from the text matter. Care should be taken to limit the number of columns so that the table can be printed without difficulty on a page 4¼ inches wide. Otherwise, rearrangement and rewriting by the editor is usually necessary. If duplicate or replicate determinations were made, only the averages should in general be submitted for publication, though the duplicate determinations may be sent for the editors' inspection. Footnotes to tabular matter should be designated by letters rather than index figures.

*Footnotes* should be numbered consecutively throughout the paper, the first number being reserved for the date of receipt of the paper for publication and such other identifying statement as may be desirable. Copy for footnotes should be inserted in the text on the line immediately following the reference, and should be cut off by ruled lines above and below. If the text is triple spaced the footnotes may be double spaced.

*Citations of Literature* may be printed as footnotes, though if they are several in number they may better appear at the end of the paper under the heading of "Literature cited." Citations so appearing should be arranged in alphabetic order and should be numbered consecutively. Reference in the text should be by this number, enclosed in parentheses. If more than one paper by an author is cited, the references should be in the order of their publication, the earliest being cited first. Citations should include the name of the author, with initials, title of article, name of publication in which it appeared, with volume and page if a periodical, and date of publication. Write "*In*" before titles of periodicals. Book citations should show place

of publication and, preferably, name of publisher. Note the following examples, and also recent issues of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY.

11. GARDNER, FRANK D. Fertility of soils as affected by manures. U. S. Dept. Agr., Bur. Soils Bul. 48, p. 54. 1908.
8. BRIGGS, L. J., and SHANTZ, H. L. The wilting coefficient for different plants and its direct determination. U. S. Dept. Agr., Bur. Plant Indus. Bul. 230, 83 p., 9 fig., 2 pl. 1912.
1. ALWAY, F. J. Studies of soil moisture in the Great Plains region. *In* Jour. Agr. Sci., 4: 333–342. 1908.
3. ALWAY, F. J. Moisture studies of semiarid soils. *In* Rpt. 79th Meeting British Asso. Adv. Sci., p. 698, 699. 1908.
14. HOPKINS, C. G. Soil Fertility and Permanent Agriculture, p. 195. Ginn & Co., Boston. 1910.

*Figures and Abbreviations.* Use Arabic numerals to express percentages and measures of quantity or space, except at the beginning of a sentence, as "9 bushels," "15 miles." Abbreviate metric weights and measures in all cases, but English weights and measures only when enclosed in parentheses, as "15 cm.," "45 bushels," but (45 bu.). Use gm. for gram(s), cm. for centimeters(s), c. c. for cubic centimeter(s), kg. for kilogram(s). Use "percent," not "per cent," "per cent.," or "%."

*Capitalization and Spelling.* Follow Webster's New International Dictionary in capitalization and spelling. Spell "sulfur," "sulfate," and their compounds with "f." Capitalize important words in citations of book titles, but use small letters in citing titles of articles or bulletins.

*Proofs.* Only one proof will be furnished. This should be read carefully, the necessary corrections indicated on the margin, and returned promptly to the editor. Do not make corrections in the text without indicating them also in the margin. Changes in figures, particularly in tabular matter, should never be written over the originals. Make only absolutely necessary changes in the proofs. The original manuscript should be so written that radical changes in the proof are unnecessary. Proof, if unaccompanied by other matter, may be mailed at the rate of 1 cent for each 2 ounces.

*Reprints.* Fifty reprints of each paper without covers are furnished free to authors. Additional reprints will be supplied at cost. Covers are supplied at the rate of $1.00 for the first 50, and 1 cent each for additional copies. Orders for reprints should always accompany the proof when it is returned.

# AGRONOMIC AFFAIRS.

## DELAY IN PUBLICATION OF THE JOURNAL.

Because of the unavoidable postponement of the annual meeting of the Society, it has been necessary to delay publication of the December number of this journal in order to include the annual reports of the officers and committees and the minutes of the annual meeting. The January, 1919, number has already been mailed and the succeeding numbers of volume 11 will be sent out on time, so far as possible.

## THE YEAR'S WORK.

As stated in the annual report of the editor, printed elsewhere in this issue, the publication of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY during 1918 has not been accomplished without difficulty. The editor has been absent from his office during the greater part of the year, and as a consequence some of the issues have been late in appearing. Not all have been up to the standard which it is desirable to maintain, while the exigencies of the times have made a reduction in the size of the annual volume necessary. The efforts of the members should now be devoted to the building up of the Society thru an increase in membership, thus making possible a larger and better publication in 1919.

## HONOR ROLL.

As the entrance of several men into military service has been reported since the last previous issue of the JOURNAL was published, it is desirable to again print the Society's honor roll, so that the record may be as complete as possible. So far as known, 55 of the Society's members have been or are now in military service, tho the list may still be far from complete. Those whose names are known to the editor are as follows:

ALBERT, A. R.,
ANDREWS, MYRON E.,
BLISS, S. W.,
BROCKSON, W. I.,
BRUCE, O. C.,
BRUNSON, A. M.,
BURNETT, GROVER,
CATES, HENRY R.,
CHAPMAN, JAMES E.,
CHILDS, R. R.,
CURREY, HIRAM E.,
DEATRICK, E. P.,
DE WERFF, H. A.,
DICKENSON, R. W.,
DOUGLAS, J. P.,
DOWNS, E. E.,
ELLISON, A. D.,
FREEMAN, RAY,
GENTLE, G. E.,
GILBERT, M. B.,
GRAHAM, E. E.,
GRAY, SAMUEL D.,
HALVERSON, W. V.,
HANSON, LEWIS P.,

| | | |
|---|---|---|
| Head, A. F., | Moomaw, Leroy, | Schoonover, W. R., |
| Helm, C. A., | Newton, Robert, | Scott, Herschel, |
| Holland, B. B., | Palmer, H. Wayne, | Smith, J. B., |
| Hudelson, R. R., | Piemeisel, R. L., | Spencer, E. L., |
| Jensen, O. F., | Purington, James A., | Stanley, C. W., |
| Karlstad, C. H., | Quigley, J. V., | Starr, S. H., |
| Kenworthy, Chester, | Ratliffe, Geo. T., | Tabor, Paul, |
| Kephart, L. W., | Raymond, L. C., | Towle, R. S., |
| Kime, P. H., | Richards, Phil E., | Ware, J. O., |
| Macfarlane, Wallace, | Schneiderhan, F. J., | Westbrook, E. C. |
| Miner, Sterling, | | |

## NOTES AND NEWS.

Roy O. Bridgeford has been elected instructor in agronomy at the Morris (Minn.) school of agriculture and F. W. McGinnis has been made instructor in farm crops in the same institution.

L. A. Clinton, for the past several years assistant chief of cooperative extension work north and west in the U. S. Department of Agriculture, on November 1 succeeded Alva M. Agee as director of extension in New Jersey. Mr. Agee will continue as State commissioner of agriculture.

Howard S. Coe, assistant agronomist in the office of forage-crop investigations, U. S. Department of Agriculture, died at Beaumont, Texas, October 25, 1918, of pneumonia following influenza. Mr. Coe was born at Orrville, Ohio, September 24, 1888. He graduated from Iowa State College in 1913 and was granted the degree of M.Sc. by the same institution in 1915. From September, 1913, to July, 1914, he was botanist and plant pathologist of the South Dakota station, resigning on the latter date to enter the service of the Department of Agriculture. His work during the past four years was for the most part in connection with studies of clover, sweet clover, velvet beans, and Southern pasture plants. He was the author of several bulletins of the Department of Agriculture and was a valued contributor to the pages of the Journal of the American Society of Agronomy, of which Society he was a member. Mr. Coe was married in September, 1914, to Lela Marie Skinner, of Brookings, S. Dak., who, with a young son, survives him. He was an energetic worker of marked ability, and his loss is keenly felt by his associates.

F. D. Farrell, for the past several years in charge of demonstration work on reclamation projects for the Department of Agriculture, since September 1 has been dean and director of the Kansas college and station.

L. H. Goddard has resigned from the States Relations Service, U. S. Department of Agriculture, to devote his entire time to his

farming interests in Ohio. His work in connection with farm management demonstrations has been taken over by the Office of Farm Management and will be directed by L. H. Moorhouse.

Aven Nelson, for the past year acting president of the University of Wyoming, has been elected president.

Ralph W. Redman, formerly of the States Relations Service, U. S. Department of Agriculture, is now assistant director of extension in Massachusetts.

C. W. Stanley, after a year's service with the Canadian Expeditionary Forces, is now assistant analyst at the Ontario Agricultural College.

F. H. Steinmetz has been elected assistant professor of farm crops and assistant agronomist of the Minnesota college and station and August Haedecke has been made assistant in agronomy of the same station.

John H. Voorhees has been added to the extension staff in farm crops at Cornell University.

W. O. Whitcomb, for the past five years assistant professor of agronomy at the Montana State College, has resigned to take charge of the Minneapolis office of the Seed Reporting Service, U. S. Department of Agriculture.

### Meeting of the New England Agronomists.

The New England agronomists held their annual meeting in Boston, November 16, 1918. Those in attedance were G. E. Simmons of Maine; M. Gale Eastman and F. W. Taylor of New Hampshire; A. B. Beaumont, H. P. Cooper, Earl Jones, and B. G. Southwick of Massachusetts; G. E. Adams of Rhode Island; and Henry Dorsey, B. C. Helmick, and W. L. Slate, jr., of Connecticut.

An informal meeting was held on the evening of November 15 at the Parker House. The seed potato question was discussed, and Professor Slate outlined his plan for inspection by the Food Administration of potatoes shipped into Connecticut. All those which do not meet the requirements for seed stock are sold for food. During the discussion, it was suggested that the New England stations try certified seed potatoes in comparison with common northern grown seed.

At the morning session on November 16 the potato score card was discussed. Professor Adams told of his experiments with certified seed and of his work with potatoes at the Rhode Island station. Professor Cooper of the Massachusetts station then talked on the grading and judging of corn. The question of how to pick out the best samples in a corn show was discussed, and it was suggested that other features might be added to corn shows, such as economical production, germination tests, milling quality, etc. Mr. Southwick of the Massachusetts college talked on the teaching of agronomy from the farm management standpoint.

A committee appointed to draft the sentiments of the New England agrono-

mists on the value of corn shows and methods of conducting them, consisting of Jones, Southwick, and Dorsey, reported as follows:

"In recognition of the fact that high-scoring corn as judged by our present scorecards may not necessarily be high-yielding corn, therefore, be it resolved that it is the sense of the New England agronomists that an attempt should be made to so modify our scorecards and other bases of comparison in judging corn that the factors of yield per acre and economical production may be given a larger recognition than at present, and that the chief object of corn shows should be to emphasize these two factors."

On the passage of this resolution, the president appointed a committee to work on the problems brought out by the discussion, assigning a problem to each member, as follows: (1) To work out a plan for experimental work with good and poor corn as judged by the scorecard, Professor Adams; (2) to work on the scorecard, Professor Cooper; and (3) to work on corn judging as related to boys' and girls' work, Mr. Eastman.

Professor Beaumont of the Massachusetts station discussed soil surveys for New England. Following the passing of a resolution urging the taking of an inventory of the soil fertility resources of New England and one authorizing the appointment of a committee of three to bring the question of soil surveys before the meeting of experiment station directors of the New England, New York, and New Jersey stations, the chair appointed a committee for this purpose consisting of Messrs. Beaumont, Simmons, and Slate.

Following a discussion of teaching after the war, a resolution urging the adoption of a four-term system instead of the semester system by New England colleges was passed, with the suggestion that if the change is made the work in crop production should be scheduled during the growing season. The secretary was instructed to send copies of this resolution to the presidents of each of the New England agricultural colleges. The secretary was also instructed to communicate with the New England Society for Rural Progress, with a view to the presentation of agronomic problems before that organization.

Professor Slate was reelected president and Professor Jones secretary and treasurer for the ensuing year.

## REPORT OF THE SECRETARY-TREASURER.

The present Secretary-Treasurer received his appointment from the President, Dr. T. Lyttleton Lyon, under date of March 11, 1918, following the resignation of Mr. P. V. Cardon. This report covers the period from that date to December 31, 1918, and includes the subscriptions, dues, etc., collected by the previous Secretary-Treasurer, subsequent to the filing of his report on March 1, 1918.

The year 1918 has been the most disastrous period in the history of the Society. In previous reports there has always been recorded a substantial growth; this one shows a decided decrease in membership. This decrease is due to several causes, perhaps most of all to the uncertainty of the positions of many of the younger members, owing to the draft. This has been an obstacle also in getting the usual number of new members. It is only fair to state, however, that the list of delinquents in the payment of dues contains the names of a number of the older agronomists. Whether these lapses were due to carelessness or were intentional, the Secretary can not say. There were some 260 members in arrears March 1. Since then two requests for payment have been sent, making three for the year.

During the period covered by this report, 23 new members have been added to the Society, 2 have died, 5 have resigned, and 98 have been dropped for nonpayment of dues. The Honor Roll of those entering the military service contains 55 names. It is quite likely that some who have been dropped for nonpayment of dues belong on the Honor Roll. If so, the Secretary will gladly make due correction if his attention is called to the error.

The Society has a paid-up membership of 509, including 10 members on the Honor Roll to whom the JOURNAL has been sent. The names and addresses of these 509 members are printed elsewhere in this issue. Together with 45 others whose names are included in the Honor Roll on page 326, the Society's membership at this time is 554. In addition to this membership list, there are 90 subscriptions to the JOURNAL from libraries and other institutions.

FINANCIAL STATEMENT FROM MARCH 11, 1918, TO DECEMBER 31, 1918.

*Receipts.*

| | | | |
|---|---|---|---|
| Received from P. V. Cardon, former Secretary | | | $1,083.60 |
| Dues from members: | | | |
| 165 members for 1918 | at $2.50 | $412.50 | |
| 1 member for 1918 | at 2.00[a] | 2.00 | |
| 1 member for 1917–18 | at 2.00 | 4.00 | |
| 4 members for 1919 | at 2.50 | 10.00 | |
| 19 new members for 1918 | at 2.50 | 47.50 | |
| 1 new member for 1918 | at 2.25[b] | 2.25 | |
| 1 new member for 1918 | at 2.00[a] | 2.00 | |

[a] Fifty cents still due to the Society.
[b] Agent's commission deducted.

| | | | |
|---|---|---|---|
| 2 new members for 1919 ............... at | 2.50 | 5.00 | |
| 2 student members for 1919 ............ at | 1.25 | 2.50 | |
| 13 local members for 1918 (N. C. section) at | .50 | 6.50 | |
| 1 advance payment on 1919 dues .......... | | 1.00 | |
| JOURNAL and *Proceedings:* | | | |
| 11 subscriptions for 1918 ................ at | 2.50 | 27.50 | |
| 5 subscriptions for 1918 ................ at | 2.25[b] | 11.25 | |
| 1 subscription for 1918 ................. at | 2.40[b] | 2.40 | |
| 12 subscriptions for 1919 ................ at | 2.25[b] | 27.00 | |
| 1 subscription for 1919 ................. at | 2.50 | 2.50 | |
| Sale of volumes previous to 1918 .......... | | 90.65 | |
| Sale of reprints .......................... | | 61.85 | |
| Interest on bank deposit .................. | | 3.83 | |
| Total recipts ........................................ | | | $1,805.83 |

*Disbursements.*

| | | | |
|---|---|---|---|
| 1918. | | | |
| March | 25. | Postage ............................................. | $ 10.00 |
| April | 1. | Maurice Joyce Eng. Co. .......................... | 6.93 |
| April | 13. | Postage ............................................. | 10.00 |
| April | 15. | Maurice Joyce Eng. Co. .......................... | 1.50 |
| April | 19. | Mary R. Burr, clerical help ...................... | 8.50 |
| May | 18. | New Era Printing Co. ........................... | 202.06 |
| June | 10. | New Era Printing Co. ........................... | 234.97 |
| June | 14. | Mary E. Burr, clerical help ...................... | 5.00 |
| July | 10. | New Era Printing Co. ........................... | 311.96 |
| July | 22. | C. W. Warburton, postage, etc. .................. | 12.00 |
| Aug. | 1. | Postage ............................................. | 8.00 |
| Aug. | 1. | Mary R. Burr, clerical help ...................... | 5.00 |
| Aug. | 30. | New Era Printing Co. ........................... | 108.74 |
| Aug. | 30. | Maurice Joyce Eng. Co. .......................... | 48.69 |
| Sept. | 4. | New Era Printing Co. ........................... | 173.80 |
| Sept. | 5. | Postage ............................................. | 10.00 |
| Oct. | 3. | Maurice Joyce Eng. Co. .......................... | 35.48 |
| Oct. | 8. | Postage ............................................. | 10.00 |
| Oct. | 8. | J. L. Wilson, postage, etc. ........................ | .65 |
| Oct. | 29. | Lewis M. Thayer, printing ........................ | 5.75 |
| Nov. | 23. | Mary R. Burr, clerical help ...................... | 17.80 |
| Dec. | 6. | Maurice Joyce Eng. Co. .......................... | 4.50 |
| Dec. | 6. | Lewis M. Thayer, printing ....................... | 4.50 |
| Dec. | 28. | Postage ............................................. | 5.00 |
| | | Total disbursements ......................... | $1,240.83 |
| | | Balance December 31, 1918 ..................... | 565.00 |
| | | | $1,805.83 |

LYMAN CARRIER,
*Secretary-Treasurer.*

By vote of the Society the report of the Secretary-Treasurer was adopted.

The report of the Editor, as published elsewhere, was read and adopted.

The report of the Committee appointed to canvass the votes on the amendment to Article 4 of the Constitution of the American Society of Agronomy to read, "The officers of The American Society of Agronomy shall be a President, a First Vice-President, a Second Vice-President, and a Secretary-Treasurer." The committee, consisting of W. B. Ellett and A. B. Beaumont, reported 183 votes for the amendment, 1 against, and 3 defective. The constitution was declared so amended.

The nominating committee, consisting of C. A. Mooers and Robert Getty, reported the following nominations:

*President,* J. G. Lipman, New Jersey Agr. Expt. Sta.
*First Vice-President,* F. S. Harris, Utah Agr. Expt. Sta.
*Second Vice-President,* A. B. Conner, Texas Agr. Expt. Sta.
*Secretary-Treasurer,* Lyman Carrier, U. S. Dept. of Agriculture.

By vote of the Society, these nominees were duly elected officers for the year 1919.

The report of the Committee on Standardization of Field Experiments, prepared by the Chairman, A. T. Wiancko, was read and adopted.

On motion, it was voted that the Executive Committee consider the advisability of affiliating with the American Association for the Advancement of Science and if thought desirable to leave the matter to a mail vote of the whole Society.

Meeting adjourned.

ADDRESS LIST OF MEMBERS.

Abell, M. F., College of Agriculture, Storrs, Conn.
Adams, G. E., Agr. Expt. Sta., Kingston, R. I.
Agee, John H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Aicher, L. C., Aberdeen Experiment Farm, Aberdeen, Idaho.
Albrecht, W. A., College of Agriculture, Columbia, Mo.
Alexander, L. L., State Normal School, Springfield, Mo.
Allen, Edward R., Agr. Expt. Sta., Wooster, Ohio.
Allyn, Orr M., Fergus, Mont.
Alvord, Emory D., Agr. Expt. Sta., Pullman, Wash.
Alway, F. J., University Farm, St. Paul, Minn.
Anderson, Arthur, University Farm, Lincoln, Nebr.
App, Frank, Rutgers College, New Brunswick, N. J.
Arny, A. C., University Farm, St. Paul, Minn.
Atkinson, Alfred, Agr. Expt. Sta., Bozeman, Mont.
Atwater, C. G., The Barrett Co., 17 Battery Place, New York, N. Y.
Ayrs, O. L., Tenn. Coal and Iron Co., Birmingham, Ala.
Babcock, F. R., County Agent, Crosby, N. Dak.
Bachtell, M. A., Ohio State University, Columbus, Ohio.
Bailey, C. H., University Farm, St. Paul, Minn.
Baker, O. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Ball, C. R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Bancroft, Ross L., Iowa State College, Ames, Iowa.
Barbee, O. E., Cliff House, Pullman, Wash.
Barre, H. W., Agr. Expt. Sta., Clemson College, S. C.

Bartlett, Harley H., 335 Packard St., Ann Arbor, Mich.
Bauer, F. C., 218 N. Lake St., Madison, Wis.
Bear, F. E., College of Agriculture, Columbus, Ohio.
Beaumont, A. B., College of Agriculture, Amherst, Mass.
Beavers, J. C., Guilford College, N. C.
Beeson, M. A., Oklahoma A. and M. College, Stillwater, Okla.
Bell, Henry G., 1111 Temple Bldg., Toronto, Canada.
Bennett, Chas. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Bennett, Hugh H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Berry, Roger E., 404 Knoblock St., Stillwater, Okla.
Biggar, H. Howard, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Billings, G. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Birchard, J. F., Magnus Ave. and Main St., Winnipeg, Canada.
Bizzell, James A., Cornell University, Ithaca, N. Y.
Blackwell, C. P., Agr. Expt. Sta., Clemson College, S. C.
Blair, R. E., Yuma Experiment Farm, Bard, Calif.
Bledsoe, R. Page, Experiment Farm, Waterville, Wash.
Block, J. F., Dept. of Interior, Calgary, Alberta, Canada.
Bolley, H. L., Agr. Expt. Sta., Agricultural College, N. Dak.
Boss, Andrew, University Farm, St. Paul, Minn.
Boving, Paul, Univ. of British Columbia, Vancouver, B. C., Canada.
Bower, H. J., Kansas State Agr. College, Manhattan, Kans.
Boyack, Breeze, Agr. Expt. Sta., Fort Collins, Colo.
Bracken, John, Saskatchewan Univ., Saskatoon, Sask., Canada.
Brandon, Jos. F., Akron Field Station, Akron, Colo.
Breithaupt, L. R., R. F. D. No. 3, Payette, Idaho.
Brewer, Herbert C., The Barrett Co., 17 Battery Place, New York, N. Y.
Briggs, Glen, Experiment Farm, Agana, Guam.
Brodie, D. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Brown, B. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Brown, E. B., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Brown, P. E., Iowa State College, Ames, Iowa.
Bryant, Ray, Stillwater, Okla.
Buckman, H. O., Cornell University, Ithaca, N. Y.
Bugby, M. O., Kingsville, Ohio.
Bull, C. P., University Farm, St. Paul, Minn.
Burdick, R. T., 635 N. California St., Stockton, Calif.
Burgess, Jas. L., Dept. Agriculture, Raleigh, N. C.
Burgess, P. S., Hawaiian Sugar Planters Expt. Sta., Honolulu, Hawaii.
Burlison, W. L., Room 607 D. Agr. Bldg., Univ. of Ill., Urbana, Ill.
Burnett, L. C., Iowa State College, Ames, Iowa.
Burr, W. W., University Farm, Lincoln, Nebr.
Burtis, Earl, 325 E. Olive St., Fort Collins, Colo.
Bushey, A. L., Plankinton, S. Dak.
Butler, Ormond R., Agr. Expt. Sta., Durham, N. H.
Call, L. E., Agr. Expt. Sta., Manhattan, Kansas.
Calvino, Mario de, Estacion Expt. Agron., Santiago de las Vegas, Cuba.
Cardon, P. V., Judith Basin Expt. Farm, Moccasin, Mont.
Carleton, M. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.

Carr, Ralph H., 24 N. Salsbury St., La Fayette, Ind.
Carrier, Lyman, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Chambliss, Chas. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Champlin, Manley, Agr. Expt. Sta., Brookings, S. Dak.
Chappelear, Geo. W., Normal Station, Harrisonburg, Va.
Chilcott, E. F., Woodward Experiment Farm, Woodward, Okla.
Childs, R. R., College of Agriculture, Athens, Ga.
Churchill, O. O., Agricultural College, N. Dak.
Clark, Chas. F., Box 747, Greeley, Colo.
Clark, Chas. H., Bur. Plant Indus., Dept. Agr., Washington, D. C.
Clark, J. Allen, Bur. Plant Indus., Dept. Agr., Washington, D. C.
Clemmer, H. J., Woodward Experiment Farm, Woodward, Okla.
Clevenger, C. B., University of Wisconsin, Madison, Wis.
Cocke, R. P., Williamsburg, Va.
Coffey, G. N., Extension Dept., Univ. of Ill., Urbana, Ill.
Cole, John S., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Coleman, L. C., Director of Agr., Bangalore, Mysore, India.
Conn, H. J., Agr. Expt. Sta., Geneva, N. Y.
Conner, A. B., Agr. Expt. Sta., College Station, Texas.
Conner, S. D., Agr. Expt. Sta., La Fayette, Ind.
Conrey, G. W., College of Agriculture, Columbus, Ohio.
Cooper, H. P., Mass. Agr. College, Amherst, Mass.
Cooper, M. L., Merryville, La.
Cowgill, H. B., Box 333, Fort Smith, Ark.
Cowles, Henry C., University of Chicago, Chicago, Ill.
Cromer, C. Otis, Agr. Expt. Sta., La Fayette, Ind.
Cron, A. B., Box 1214, Amarillo, Texas.
Cunningham, C. C., Agr. Expt. Sta., Manhattan, Kans.
Curtis, H. P., County Agent, Sutton, W. Va.
Cutler, G. H., Univ. of Alberta, Edmonton South, Alta., Canada.
Daane, Adrian, 225 Duncan St., Stillwater, Okla.
Damon, S. C., Agr. Expt. Sta., Kingston, R. I.
Darst, W. H., Dept. Agr., State College, Penn.
Davidson, Jehiel, Bur. Chemistry, U. S. Dept. Agr., Washington, D. C.
Davis, R. O. E., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Dean, H. K., Umatilla Experiment Farm, Hermiston, Ore.
Deatrick, Eugene P., Kutztown, Penn.
Delwiche, E. J., 1221 Chicago St., Green Bay, Wis.
Dillman, A. C., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Doneghue, R. C., Agr. Expt. Sta., Agricultural College, N. Dak.
Dorsey, Henry, College of Agriculture, Storrs, Conn.
Duley, F. L., 705 Hill St., Columbia, Mo.
Dunnewald, T. J., 210 N. Carrol St., Madison, Wis.
Dunton, Leila, Agr. Expt. Sta., Manhattan, Kans.
Dustman, Robt. B., Agr. Expt. Sta., Morgantown, W. Va.
Dynes, O. W., College of Agriculture, Ithaca, N. Y.
Ellett, W. B., Agr. Expt. Sta., Blacksburg, Va.
Emerson, Paul, Agr. Expt. Sta., College Park, Md.
Engle, C. C., College of Agriculture, New Brunswick, N. J.

Erdman, Lewis W., Agr. Expt. Sta., College Park, Md.
Etheridge, W. C., Agr. Expt. Sta., Columbia, Mo.
Evans, M. W., North Ridgeville, Ohio.
Ewing, E. C., Scott, Miss.
Fain, Jno. R., University of Georgia, Athens, Ga.
Farrell, F. D., Agr. Expt. Sta., Manhattan, Kans.
Fergus, E. N., Agr. Expt. Sta., La Fayette, Ind.
Ferguson, A. M., Ferguson Seed Farms, Sherman, Texas.
Fippin, E. O., Agr. Expt. Sta., Ithaca, N. Y.
Firkins, Bruce J., Dept. of Soils, I. S. C., Ames, Iowa.
Fisher, Forest A., Agr. Expt. Sta., Urbana, Ill.
Fisher, M. L., Purdue University, La Fayette, Ind.
Fitz, L. A., Agr. Expt. Sta., Manhattan, Kans.
Fletcher, C. C., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Florell, Victor H., Plant Introduction Garden, Chico, Calif.
Foesterling, H., Arbor Farms, Jamesburg, N. J.
Foord, Jas. A., 54 Lincoln Ave., Amherst, Mass.
Fraps, G. S., Agr. Expt. Sta., College Station, Texas.
Frear, D. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Fred, Edwin B., College of Agriculture, Madison, Wis.
Free, E. E., 1105 Madison Ave., Baltimore, Md.
Freeman, Geo. F., Societie Sultanienne d'Agriculture, Cairo, Egypt.
Freeman, H. A., Experiment Farm, Ottawa, Canada.
French, W. L., Austin, Minn.
Furry, R. L., Ferguson Seed Co., Sherman, Texas.
Gaddis, P. L., University Farm, Lincoln, Nebr.
Gaines, E. F., Agr. Expt. Sta., Pullman, Wash.
Galbraith, A. J., Manitoba Agr. Col., Winnepeg, Man., Canada.
Garber, R. J., University Farm, St. Paul, Minn.
Gardner, F. D., Agr. Expt. Sta., State College, Penn.
Garren, G. M., P. O. Box 199, Raleigh, S. Dak.
Garver, Samuel, Forage Crop Field Sta., Redfield, S. Dak.
Gentle, G. E., Agr. Expt. Sta., Urbana, Ill.
Gericke, W. F., Agr. Expt. Sta., Berkeley, Calif.
Gernert, W. B., Farm Bureau, Paris, Ill.
Getty, Robt. E., Branch Expt. Sta., Hays, Kans.
Gilbert, M. B., Woodburn, Oregon.
Gile, Philip L., 43 Briggs St., Melrose Highlands, Mass.
Gillis, M. C., 401 E. Douglas St., Bloomington, Ill.
Gilmore, John W., College of Agriculture, Berkeley, Calif.
Goddard, L. H., Washington Avenue, Washington C. H., Ohio.
Goodall, S. E., Owensmouth, Calif.
Gordon, Thomas B., Massachusetts Agr. College, Amherst, Mass.
Graber, L. F., Wis. Agr. Expt. Assoc., Madison, Wis.
Granovsky, Alexander, 320 Plum St., Fort Collins, Colo.
Grantham, A. E., Agr. Expt. Sta., Newark, Del.
Grantham, Geo. M., Agr. Expt. Sta., East Lansing, Mich.
Grimes, W. E., Kansas State Agr. College, Manhattan, Kans.
Gustafson, A. F., 962 State St., Ithaca, N. Y.

Hackelman, J. C., Agr. Expt. Sta., Columbia, Mo.
Hagy, F. S., 924 Fremont St., Manhattan, Kans.
Hall, Thomas D., College of Agr., Potchefstroom, South Africa.
Hallsted, A. L., Branch Expt. Sta., Hays, Kans.
Halverson, W. V., R. F. D. No. 2, Spanish Fork, Utah.
Hansen, Dan, Huntley Experiment Farm, Huntley, Mont.
Hardenburg, E. V., Dept. Farm Crops, Col. Agr., Ithaca, N. Y.
Harlan, H. V., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Harlow, L. C., Agricultural College, Truro, N. S., Canada.
Harris, F. S., Agr. Expt. Sta., Logan, Utah.
Harrison, T. J., College of Agriculture, Winnipeg, Man., Canada.
Hartley, C. P., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Hartwell, Burt L., Agr. Expt. Sta., Kingston, R. I.
Haseltine, L. E., 2301 Durant Ave., Berkeley, Calif.
Haskell, S. B., 1429 Munsey Bldg., Baltimore, Md.
Hatcher, Otto, 318 West St., Stillwater, Okla.
Hayes, Herbert K., University Farm, St. Paul, Minn.
Headley, F. B., Truckee Carson Field Station, Fallon, Nev.
Hearn, W. E., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Hechler, W. R., College of Agriculture, Ames, Iowa.
Hendry, Geo. W., College of Agriculture, Berkeley, Calif.
Hildebrand, E. B., 112 N. Main St., Stillwater, Okla.
Hill, C. E., Experiment Farm, Moro, Ore.
Hill, H. H., Agr. Expt. Sta., Blacksburg, Va.
Hill, W. H., 326 Howe St., Vancouver, B. C., Canada.
Hodgson, E. R., Agr. Expt. Sta., Blacksburg, Va.
Holt, S. V., Experiment Farm, Rio, Ill.
Hopkins, E. S., School of Agriculture, Olds, Alberta, Canada.
Hopt, Erwin, University Farm, Lincoln, Nebr.
Horton, Horace E., 208 LaSalle St., Chicago, Ill.
Hotchkiss, W. S., Substation No. 2, Troup, Texas.
Hudelson, R. R., Agr. Expt. Sta., Columbia, Mo.
Huelskemper, Ed., 411 Terry St., Longmont, Colo.
Hulbert, H. W., University of Idaho, Moscow, Idaho.
Humbert, Eugene P., Agr. Expt. Sta., College Station, Texas.
Hume, A. N., College of Agriculture, Brookings, S. Dak.
Hungerford, DeF., College of Agriculture, Fayetteville, Ark.
Hunnicutt, B. H., Escola Agricola de Lavras, E. de Minas, Brazil.
Hurst, J. B., 111 Knoblock St., Stillwater, Okla.
Huston, H. A., German Kali Works, 43 Broadway, New York, N. Y.
Hutcheson, T. B., Agr. Expt. Sta., Blacksburg, Va.
Hutchison, C. B., College of Agriculture, Ithaca, N. Y.
Hutchison, Geo. S., Albert Dickinson Co., Chicago, Ill.
Hutton, J. G., Agr. Expt. Sta., Brookings, S. Dak.
Iberico, Juan R., Yurimaguas, Loreto, Peru, via Para, Brazil.
Igo, Jerome, 228 W. Magnolia St., Fort Collins, Colo.
Israelson, Orson F., College of Agriculture, Logan, Utah.
Jackson, L. D., Western Canada Flour Mills Co., Winnipeg, Man.
Jacobs, Daniel C., R. F. D. No. 5, Gettysburg, Pa.

Jardine, W. M., Kansas State Agr. College, Manhattan, Kans.
Jarrell, J. F., Great Western Sugar Co., Longmont, Colo.
Jenkins, J. Mitchell, Rice Experiment Station, Crowley, La.
Jensen, L. N., Box 308, Big Springs, Texas.
Johnson, D. R., 220 Knoblock St., Stillwater, Okla.
Johnson, Geo. F., 256 W. Woodruff Ave., Columbus, Ohio.
Johnson, T. C., Va. Truck Expt. Sta., Norfolk, Va.
Jones, Earl, Mass. Agricultural College, Amherst, Mass.
Jones, J. W., Rice Field Station, Biggs, Calif.
Jones, S. C., Agr. Expt. Sta., La Fayette, Ind.
Joslyn, H. L., Farm Life School, Vanceboro, N. C.
Justin, M. M., 442 State Capitol, Salt Lake City, Utah.
Kan, F. F., P. O. Box 95, College Station, Texas.
Karper, R. E., Lubbock Substation, Lubbock, Texas.
Karraker, P. E., Agr. Expt. Sta., Lexington, Ky.
Kearney, T. H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Keim, Frank D., University Farm, Lincoln, Nebr.
Kellerman, K. F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Kelley, W. P., Citrus Experiment Station, Riverside, Calif.
Kelly, E. O. G., Wellington, Kans.
Kemp, W. B., Sparks, Md.
Kennard, F. L., Colfax, Wash.
Kennedy, P. B., 11 Budd Hall, Univ. of Calif., Berkeley, Calif.
Kephart, L. W., Bur. Plant Indus., U. S. Dept. of Agr., Washington, D. C.
Kezer, Alvin, Agr. Expt. Sta., Fort Collins, Colo.
Kidder, A. F., Agricultural College, Baton Rouge, La.
Kiesselbach, T. A., Agr. Expt. Sta., Lincoln, Nebr.
Kilgore, B. W., State Dept. Agr., Raleigh, N. C.
Killough, D. T., Substation No. 5, Temple, Texas.
Kinney, E. J., Agr. Expt. Sta., Lexington, Ky.
Kirk, N. M., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Klein, Millord A., Spreckles Sugar Co., Spreckles, Calif.
Klinck, L. S., University of British Columbia, Victoria, B. C., Canada.
Knight, Chas. S., University of Nevada, Reno, Nev.
Kraft, J. H., State Teachers College, Greeley, Colo.
Krall, John A., County Agent, Manchester, Iowa.
Krauss, F. G., Supt. Extension Work, Haiku, Hawaii.
Krusekopf, H. H., Agricultural College, Columbia, Mo.
Kuska, J. B., Experiment Farm, Colby, Kansas.
Langenbeck, Karl, 1625 Hobart St., N. W., Washington, D. C.
Lapham, Macy H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
LaTourette, Lyman D., R. F. D. No. 1, Phoenix, Ariz.
Laude, Hilmer H., R. F. D. No. 1, Beaumont, Texas.
LeClerc, J. A., Bureau of Chemistry, U. S. Dept. Agr., Washington, D. C.
Ledyard, E. M., U. S. Smelting Co., Salt Lake City, Utah.
Leidigh, A. H., Agr. Expt. Sta., College Station, Texas.
Leighty, C. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Leith, B. D., University of Wisconsin, Madison, Wis.
Leonard, Lewis T., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.

Lipman, C. B., Agr. Expt. Sta., Berkeley, Calif.
Lipman, J. G., Agr. Expt. Sta., New Brunswick, N. J.
Lippitt, W. D., 300 Sugar Bldg., Denver, Colo.
Löhnis, F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Loomis, Howard, S. Dak. State College, Brookings, S. Dak.
Lora, Armando, Aguiar 47, Havana, Cuba.
Love, H. H., Cornell University, Ithaca, N. Y.
Love, Russell M., R. F. D. No. 2, Tarentum, Penn.
Lowry, Marion W., College of Agriculture, Athens, Ga.
Luäces, Roberto, Granja Escuela, Camaguey, Cuba.
Lund, Viggo, Tystoftu Expt. Sta., Tjaereby, Denmark.
Lynde, C. J., Macdonald College, Quebec, Canada.
Lyon, T. Lyttleton, Cornell University, Ithaca, N. Y.
McCall, A. G., Agr. Expt. Sta., College Park, Md.
McCall, M. C., Experiment Farm, Lind, Wash.
McClelland, C. K., Agr. Expt. Sta., Experiment, Ga.
McDowell, C. H., Substation No. 6, Denton, Texas.
McGuffey, C. Carl, McGuffey, Ohio.
McHenry, Norris, R. F. D. No. 20, Elizabethtown, Ind.
McIlvaine, T. C., R. F. D. No. 4, Huntington, W. Va.
McKee, Clyde, Iowa State College, Ames, Iowa.
McKee, Roland, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
McLane, J. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
McMillan, S. A., Texas A. and M. College, College Station, Texas.
McMiller, P. R., University Farm, St. Paul, Minn.
McNess, G. T., Experiment Farm, Nacogdoches, Texas.
Mackie, W. W., 121 Hilgard Hall, University of California, Berkeley, Calif.
Madson, B. A., Agr. Expt. Sta., Davis, Calif.
Maier, Fred, 400 S. Howes St., Fort Collins, Colo.
Mally, F. W., Laredo, Texas.
Maris, Edwin J., Demonstration Agent, Atwood, Kans.
Martin, John H., Harney Branch Station, Burns, Ore.
Maxson, A. C., Great Western Sugar Co., Longmont, Colo.
Merkle, Fred G., Agricultural College, Amherst, Mass.
Metzger, J. E., College Park, Md.
Millar, C. E., Agricultural College, East Lansing, Mich.
Miller, Edwin C., Agricultural College, Manhattan, Kans.
Miller, M. F., Agr. Expt. Sta., Columbia, Mo.
Milton, Roy H., Clarksville, Tenn.
Miner, Sterling, 1029 Sixth St., Greeley, Colo.
Miyake, Koji, College of Agriculture, Tohoku Imp. Univ., Sapporo, Japan.
Monteaguda, Heriberto de, Quinta de los Molinos, Habana, Cuba.
Montgomery, E. G., College of Agriculture, Ithaca, N. Y.
Mooers, Chas. A., Agr. Expt. Sta., Knoxville, Tenn.
Moore, Harvey L., 111 N. Willow St., Trenton, N. J.
Moore, R. A., University of Wisconsin, Madison, Wis.
Moorhouse, L. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Morgan, J. O., Agr. Expt. Sta., College Station, Texas.
Morgan, O. S., Columbia University, New York, N. Y.

Morrison, J. D., Elbon, S. Dak.
Morse, W. J., 6809 Fifth St., Takoma Park, D. C.
Mortimer, Geo. B., College of Agriculture, Madison, Wis.
Mosher, M. L., Eureka, Ill.
Mosier, J. G., Agr. Expt. Sta., Urbana, Ill.
Murray, Jas., Macdonald College, Quebec, Canada.
Musback, Fred L., Marshfield, Wis.
Myers, C. H., College of Agriculture, Ithaca, N. Y.
Nash, C. W., Morris, Minn.
New, T., Tsing Hua College, Peking, China.
Newman, L. H., Canadian Building, Ottawa, Canada.
Newton, Robert, Woodstock, New Brunswick, Canada.
Oakley, R. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Olson, Geo. A., Agr. Expt. Sta., Pullman, Wash.
Olson, P. J., R. F. D. No. 1, Grafton, N. Dak.
Osborn, L. W., Agr. Expt. Sta., Fayetteville, Ark.
Osler, H. S., Court House, Ann Arbor, Mich.
Pammel, L. H., Agr. Expt. Sta., Ames, Iowa.
Park, J. B., College of Agriculture, Columbus, Ohio.
Parker, John H., Agr. Expt. Sta., Manhattan, Kans.
Pate, W. F., Agr. Expt. Sta., West Raleigh, N. C.
Patterson, H. J., Agr. Expt. Sta., College Park, Md.
Paxton, Glenn, P. O. Box 269, Fort Collins, Colo.
Pendleton, Robert L., Ewing Christian College, Allahabad, India.
Peterson, W. A., Mandan, N. Dak.
Petry, Edward J., 210 S. Ingalls St., Ann Arbor, Mich.
Phillips, Thos. G., College of Agriculture, Columbus, Ohio.
Pieters, A. J., 340 Blair Road, Takoma Park, D. C.
Piper, C. V., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Pittman, D. W., Agr. Expt. Sta., Logan, Utah.
Plummer, J. K., Agr. Expt. Sta., Raleigh, N. C.
Pope, M. N., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Pridmore, J. C., 616 Rhodes Bldg., Atlanta, Ga.
Rast, Loy E., State College of Agriculture, Athens, Ga.
Reed, Everett P., Agr. Expt. Sta., Geneva, N. Y.
Reed, H. R., Yuma Field Station, Bard, Calif.
Reid, F. R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Reynolds, E. B., Substation No. 3, Angleton, Texas.
Rice, Thos. D., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Riley, J. A., Chester, S. C.
Robbins, F. E., 432 Russell St., West La Fayette, Ind.
Roberts, Geo., Agr. Expt. Sta., Lexington, Ky.
Roberts, J. M., Central Scientific Co., 345 W. Mich. Ave., Chicago, Ill.
Ross, Jno. F., Cereal Field Station, Amarillo, Texas.
Rost, C. O., University Farm, St. Paul, Minn.
Rothgeb, B. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Roudebush, R. I., West Liberty, W. Va.
Rueda, Buenaventura, Linea 7, Antiguo 8 y 10, Vedado, Havana, Cuba.
Runk, C. R., 250 West 10th Ave., Columbus, Ohio.

Russell, J. C., University Place, Lincoln, Neb.
Ruzek, C. V., Agr. Expt. Sta., Corvallis, Ore.
Salmon, S. C., Agr. Expt. Sta., Manhattan, Kans.
Salter, Robt. M., Agr. Expt. Sta., Morgantown, W. Va.
Sarvis, J. T., Northern Great Plains Field Sta., Mandan, N. Dak.
Schafer, E. G., State College, Pullman, Wash.
Schaub, I. O., States Rel. Service, U. S. Dept. Agr., Washington, D. C.
Schmitz, Nickolas, Extension Dept., State College, Pa.
Schoth, Harry A., Agr. Expt. Sta., Corvallis, Ore.
Schreiner, Oswald, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Schuer, H. W., 247 W. Tenth St., Columbus, Ohio.
Schuster, G. L., Lancaster High School, Lancaster, Ohio.
Scofield, C. S., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Seamans, Arthur, Huntley Experiment Farm, Huntley, Mont.
Sears, O. H., 502 Waldron St., La Fayette, Ind.
Sewell, M. C., College of Agriculture, Manhattan, Kans.
Shantz, H. L., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Shaw, Chas. F., Agr. Expt. Sta., Berkeley, Calif.
Shepperd, John H., Agr. Expt. Sta., Agricultural College, N. Dak.
Sherwin, M. E., College of Agriculture, West Raleigh, N. C.
Shutt, Frank T., Central Experiment Farms, Ottawa, Canada.
Seiglinger, J. B., Woodward Field Station, Woodward, Okla.
Simard, J. A., Box 211, Quebec, P. Q., Canada.
Skinner, J. J., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Simmons, Geo. E., University of Maine, Orono, Maine.
Slate, W. L., jr., Agr. Expt. Sta., Storrs, Conn.
Slipher, John A., Agr. Expt. Sta., La Fayette, Ind.
Smith, L. H., College of Agriculture, Urbana, Ill.
Smith, Nelson S., School of Agriculture, Olds, Alta., Canada.
Smith, Ralph W., Dickinson Substation, Dickinson, N. Dak.
Smith, Raymond S., 304 Elmwood Ave., Ithaca, N. Y.
Smith, V. C., College of Agriculture, Columbus, Ohio.
Snyder, Harry, 1800 Summit Ave., Minneapolis, Minn.
Southwick, Benj. G., College of Agriculture, Amherst, Mass.
Southwick, Everett, 208 Lowell St., Peabody, Mass.
Southworth, W., Manitoba Agr. College, Winnipeg, Man., Canada.
Spillman, W. J., Northbrook Courts, Washington, D. C.
Spragg, F. A., Agr. Expt. Sta., East Lansing, Mich.
Squires, J. H., Technical Div., Dupont Powder Co., Wilmington, Del.
Stadler, L. J., 410 S. Maple St., St. Louis, Mo.
Stanley, Clarence W., Ontario Agr. College, Guelph, Ont., Canada.
Stanton, T. R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Stemple, F. W., College of Agriculture, Morgantown, W. Va.
Stephens, David E., Experiment Farm, Moro, Ore.
Stephenson, R. E., Iowa State College, Ames, Iowa.
Stevenson, W. H., Agr. Expt. Sta., Ames, Iowa.
Stewart, George, Agr. Expt. Sta., Logan, Utah.
Stewart, H. W., 2010 Monroe St., Madison, Wis.
Stewart, Rupert L., College of Agriculture, State College, N. Mex.

Stoa, Theodore E., Agr. Expt. Sta., Agricultural College, N. Dak.
Stockberger, W. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Stokes, W. E., Edgefield, S. C.
Stone, J. L., Agr. Expt. Sta., Ithaca, N. Y.
Stookey, E. B., Western Washington Expt. Sta., Puyallup, Wash.
Summerby, R., Macdonald College, Quebec, Canada.
Taggart, J. G., School of Agriculture, Olds, Alta., Canada.
Taliaferro, W. T. L., Agricultural College, College Park, Md.
Taylor, F. W., Agr. Expt. Sta., Durham, N. H.
Thatcher, L. E., Agr. Expt. Sta., Wooster, Ohio.
Thatcher, R. W., University Farm, St. Paul, Minn.
Thomas, Melvin, Charleston, Ill.
Thompson, G. E., Agr. Expt. Sta., Tucson, Ariz.
Thompson, James, Col. of Pharmacy, Univ. of Wash., Seattle, Wash.
Thompson, R. S., Highland, Calif.
Thorne, Chas. E., Agr. Expt. Sta., Wooster, Ohio.
Throckmorton, R. I., College of Agriculture, Manhattan, Kans.
Thysell, John C., Dickinson Substation, Dickinson, N. Dak.
Tillman, B. W., University of Missouri, Columbia, Mo.
Tinsley, J. D., 507 Union Station, Galveston, Texas.
Tracy, S. M., Biloxi, Miss.
Trout, C. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
True, R. H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Truog, Emil, Agr. Expt. Sta., Madison, Wis.
Turlington, J. E., University of Florida, Gainesville, Fla.
Turner, A. F., College of Agriculture, Manhattan, Kans.
Tuttle, H. Foley, College of Agriculture, Urbana, Ill.
Umberger, H. J. C., Extension Div., Col. of Agr., Manhattan, Kans.
Van Alstine, Ernest, 912 Nevada St., Urbana, Ill.
Vanatter, P. O., College of Agriculture, Athens, Ga.
Van Nuis, C. S., College Farm, New Brunswick, N. J.
Van Schaick, K. L., Pretoria, Transvaal, South Africa.
Veach, C. L., College of Agriculture, Athens, Ga.
Veitch, F. P., Bur. Chemistry, U. S. Dept. Agr., Washington, D. C.
Viola, G. E., Oak and Spring Sts., West Hoboken, N. J.
Vinall, H. N., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Vivian, Alfred, Ohio State University, Columbus, Ohio.
Voorhees, John H., Extension Dept., Cornell Univ., Ithaca, N. Y.
Waldron, L. R., Agr. Expt. Sta., Agricultural College, N. Dak.
Waller, Adolph E., Ohio State University, Columbus, Ohio.
Waller, Allen G., 2028 F St., N. W., Washington, D. C.
Walster, H. L., Agr. Expt. Sta., Madison, Wis.
Walter, E. J., 91 West Eleventh St., Columbus, Ohio.
Walworth, E. H., Martinsville, Ill.
Warburton, C. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Welch, J. S., L. D. S. Maori Agr. College, Hastings, New Zealand.
Wells, W. G., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Welton, F. A., Agr. Expt. Sta., Wooster, Ohio.
Wentz, John B., Maryland State College, College Park, Md.

Wermelskerchen, Louis, Agr. Expt. Sta., College Station, Texas.
West, J. T., Agricultural College, Miss.
Westgate, J. M., Agr. Expt. Sta., Honolulu, Hawaii.
Westley, Roy, N. W. School of Agr., Crookston, Minn.
Westover, H. L., Yuma Experiment Farm, Bard, Calif.
Wheeler, Clark S., 423 W. Ninth St., Columbus, Ohio.
Wheeler, H. C., Agricultural Bldg., Col. of Agr., Urbana, Ill.
Wheeler, H. J., 111 Grant Ave., Newton Center, Mass.
Whitcomb, W. O., 320 Flour Exchange, Minneapolis, Minn.
Whiting, A. L., 705 Gregory St., Urbana, Ill.
Whitson, A. R., Agr. Expt. Sta., Madison, Wis.
Wiancko, A. T., Agr. Expt. Sta., La Fayette, Ind.
Widtsoe, John A., University of Utah, Salt Lake City, Utah.
Wiggans, Roy G., Cornell University, Ithaca, N. Y.
Wilkins, F. S., College of Agriculture, Ames, Iowa.
Wilkinson, J. V., 624 Egan St., Shreveport, La.
Will, Geo. F., Bismarck, N. Dak.
Willard, C. J., Ohio State University, Columbus, Ohio.
Willey, Leroy D., Box 879, Sheridan, Wyo.
Williams, Chas. B., Agr. Expt. Sta., West Raleigh, N. C.
Williams, C. G., Agr. Expt. Sta., Wooster, Ohio.
Wilson, Benj. D., Cornell University, Ithaca, N. Y.
Wilson, Bruce S., Agr. Expt. Sta., Manhattan, Kans.
Wimer, David C., Pa. State College, State College, Pa.
Winters, N. E., Extension Dept., College of Agr., West Raleigh, N. C.
Winters, R. Y., Agr. Expt. Sta., West Raleigh, N. C.
Withycombe, Robert, Union, Ore.
Wolfe, T. K., Agr. Expt. Sta., Blacksburg, Va.
Wooward, John, Mt. Morris College, Mt. Morris, Ill.
Woods, A. F., Maryland State College, College Park, Md.
Woodworth, C. M., Agr. Hall, Univ. of Wis., Madison, Wis.
Worsham, W. A., College of Agriculture, Athens, Ga.
Wright, A. H., Dept. of Agronomy, College of Agr., Madison, Wis.
Wright, R. Claude, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Wunsch, W. A., County Agent, Newton, Kans.
Wyatt, F. A., 216 Agr. Bldg., University of Illinois, Urbana, Ill.
Yoder, P. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Young, Philip H., Agr. Expt. Sta., Manhattan, Kans.
Youngblood, Bonney, Agr. Expt. Sta., College Station, Texas.
Zavitz, C. A., Ontario Agr. College, Guelph, Ont., Canada.
Zinn, Jacob, Agr. Expt. Sta., Orono, Maine.
Zook, L. L., North Platte Substation, North Platte, Nebr.

## Lapsed Members.

The following have lapsed for non-payment of 1918 dues:

Adams, E. L.,
Barker, Joseph F.,
Bergh, Otto I.,
Binford, E. E.,
Boardman, W. C.,
Bolland, J.,
Bonazzi, A.,
Bonnett, R. R.,
Booth, V. J.,
Bouyoucos, S. J.,
Carroll, J. S.,
Carter, L. M.,

Collins, M. W. H.,
Cook, I. S., Jr.,
Cox, Jos. F.,
Crabb, Geo. A.,
Cramer, W. F.,
Criswell, Judson,
Crosby, M. A.,
Davison, W.,
Derr, H. B.,
Dickson, R. E.,
Doryland, C. J. T.,
Dougall, Robert,
du Buisson, J. P.,
Duggar, J. F.,
Ellis, Orland I.,
Ewan, A. E.,
Finnell, H. H.,
Fleming, Frank L.,
Fletcher, O. S.,
Foreman, L. W.,
Frank, W. L.,
Gilkerson, H. C.,
Gish, N. A.,
Guell, Aurelio R.,
Hanger, W. E.,
Hanson, H. P.,
Harrington, O. E.,
Haskell, E. S.,
Hill, P. R.,
Hodson, Edgar A.,
Hoke, Roy,
Holbert, J. R.,
Hopkins, Cyril G.,
Hurst, J. B.,
Hutchinson, W. L.,
Hyslop, Geo. R.,
Jackson, J. W.,
Jarvis, Orin W.,
Kemp, Arnold R.,
Kenney, Ralph,
Knutson, George,
Lechner, H. J.,
Letteer, C. R.,
Livingston, Geo.,
Long, David D.,
Longman, O. S.,
Luckett, J. D.,
McClymonds, A. E.,
McIntire, W. H.,
Marbut, C. F.,
Martin, Thos. L.,
Mathews, Oscar R.,
Maughan, Howard J.,
Miller, Frank R.,
Milner, F. W.,
Morison, A. T.,
Moynan, J. C.,
Mundell, J. E..
Murphy, Henry,
Nevin, L. B.,
Newman, C. L.,
Noyes, H. A.,
Olson, M. E.,
Osenbrug, Albert,
Prince, Ford S.,
Pritchard, F. J.,
Richey, F. D.,
Robertson, R. B.,
Rose, C. N.,
Schultz, H. H.,
Severance, George,
Shinn, E. H.,
Shoesmith, V. M.,
Sink, Stanley B.,
Smith, Howard C.,
Snyder, Robert M.,
Stewart, Robert,
Torgerson, E. F.,
Townsend, C. O.,
Van Evera, R.,
Wallace, R. C. E.,
Ward, Wylie,
Wascher, F. M. W.,
Winsor, L. M.,
Winwright, George,
Woo, Moi Lee.

## MINUTES OF THE ELEVENTH ANNUAL MEETING.

BALTIMORE, MD., JANUARY 6–7, 1919.

*First Session, Monday Afternoon, January 6.*

The meeting was called to order by the Secretary-Treasurer in the absence of President Lyon and Prof. J. H. Shepperd was appointed Chairman. The following papers were presented:

1. Effect of Varying Degrees of Heat on the Viability of Seeds, by James L. Burgess (followed by a discussion).

2. Field Crop Inspection, a Necessity to Standardization and Crop Improvement in Cereals, by H. L. Bolley (read by J. H. Shepperd).

*Second Session, Monday Evening, January 6.*

Dr. Herbert Osborn, presiding.

Some Observations on Agricultural Conditions in England and France, by Dr. W. O. Thompson.

Influence of Higher Plants on Bacterial Activities in Soils, by Dr. T. L. Lyon, President of the American Society of Agronomy (read by Dr. C. E. Leighty).

The Problems of Permanent Pasture with Special Reference to its Biological Factors, by Dr. Herbert Osborn, President of the Society for the Promotion of Agricultural Science.

*Third Session, Tuesday Morning, January 7.*

3. The Small Grain Varieties of Utah, by George Stewart (read by F. S. Harris).

4. Fertilizer Experiments on DeKalb Soils, by Frank D. Gardner.

5. Green Sand Deposits as a Source of Potassium for Crops, by R. H. True.

6. Carrying Capacity of Native Range Grasses, by J. H. Shepperd.

*Fourth Session, Tuesday Afternoon, January 7.*

7. A Method for Determining the Proper Stand of Corn under Southern Conditions, by C. A. Mooers.

8. The Work of the Committee on Seed Stocks, by R. A. Oakley.

9. A Reason for the Contradictory Results in Corn Experiments, by Lyman Carrier.

*Business Meeting.*

The report of the Secretary-Treasurer, as presented elsewhere in this issue, was read.

The report of the Auditing Committee was then read by the Chairman, Frank D. Gardner, as follows:

### Report of Auditing Committee.

Your committee has audited the accounts of the Society by the Secretary-Treasurer, Lyman Carrier, and find them to be correct.

(*Signed*) Frank D. Gardner,
C. F. Marbut,
*Committee.*

## REPORT OF THE COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

In the work of the Committee on the Standardization of Field Experiments, it was thought advisable this year to make a survey of the methods actually followed by investigators employing field plot experiments. The task of collecting this information was divided among the members of the committee, one taking the questions relating to size, shape, and arrangement of plots employed in soil-fertility investigations; another taking similar questions relating to field experiments with crops, and the third taking the questions regarding the use and management of check plots. In each case questionnaires were prepared and sent to the workers along these lines in the experiment stations thruout the United States. It was felt that the information thus gathered would be of value to the members of the Society and would be helpful later on in formulating some general rules for the guidance of experimenters planning new work along these lines.

### FIELD-PLOT METHODS IN SOIL-FERTILITY INVESTIGATIONS.

*Size of Plot.*—The answers to the question regarding the size of plots employed in soil-fertility experiments showed that nearly all of the experiment stations are using several different sizes of plots. There are various reasons for this. In many cases the area of land available has been the determining factor. Sometimes the nature and extent of the particular experiment has influenced the size of plot employed. More often the ideas of the experimenter as regards the most suitable and convenient size of plot have been the determining factor and so successive workers making additions to field-plot experiments have laid out plots of different sizes. Even tho the work is quite similar in nature, we thus have sometimes as many as a half dozen different sized plots in the same experiment field.

Among the 29 stations answering the question, the sizes of plots employed vary from 1 acre down to 1/200 of an acre. It was not possible to tell from the answers just how many different sizes of plots are employed, because in many cases the question was answered by merely naming the extremes of variation in size. Neither was it possible to get an accurate idea of the average size of plots used, but it is probably somewhere between one-tenth and one-twentieth acre. Only one of the 29 stations is using plots as large as 1 acre or as small as 1/200 acre. Tenth-acre and twentieth-acres plots largely predominate, and fortieth-acre plots appear to stand next in numbers. Only a few stations are using plots larger than tenth-acre or smaller than fortieth acre. A few of the stations are using quarter-acre, fifth-acre, eightieth-acre, or hundredth-acre plots. In answer to the question, "What do you consider the ideal size of plot?", the great majority suggested the twentieth-acre and tenth-acre sizes. Only a few favored either larger or smaller plots for ordinary purposes.

*Shape of Plot.*—Twenty-two of the twenty-nine stations more or less definitely answered this question and it appears that the variations in shape are even greater than the variations in size. Nearly every experimenter has a different idea as to the best or most convenient shape of plot. In 20 of the 22 cases where shape of plot is specified, more or less rectangular plots are used, and in the majority of cases they are decidedly long and narrow. Variations run from twice to ten times as long as wide. In two cases square plots are used.

It was brought out in many of the replies that both size and shape of plot must necessarily vary according to the acreage and character of the land available and that no fixed system can be followed in all cases.

*Arrangement of Plots to Overcome Variations in Soil Fertility.*—The importance of arranging series of plots so as to equalize soil differences as much as possible is generally recognized by experienced investigators. A common practice is to lay off long, narrow plots at right angles to the main soil variations and to provide for making corrections for the variations in the other direction by the use of frequent uniformly treated check plots. The repetition of series of plots so as to have a similarly treated series for each crop in the rotation helps to equalize variations. Such repetition of series provides for overcoming the effects of seasonal variations upon different crops by making it possible to grow the several crops employed in the rotation every year. This, together with frequent checks and averaging the similarly treated plots in the several series over a period of years, is generally considered sufficient to overcome ordinary variations.

*Replication of Trials.*—On this point, it was not possible from the answers to tell to what extent replication is practiced. The question was evidently interpreted in two different ways, some taking it to mean the number of similarly treated sets of plots and others the number of times the whole experiment is repeated. In most cases, however, each series of plots is repeated as many times as there are crops in the rotation followed, as for example, a 4-year rotation of corn, oats, wheat, and hay would have four sets of similarly treated plots, one set for each crop and all crops grown every year. Actual replication of whole series of experiments is practiced by only a few of the stations, tho several expressed themselves in favor of it wherever practicable. However, the large amount of land and labor required is a practical difficulty involved in the frequent replication of field-plot experiments, which usually include a considerable number of plots.

*Spaces and Borders.*—As regards spaces between plots and borders around series, the practice is to have narrow untreated strips between plots and untreated borders around series, planted to the same crop and cut out or trimmed off at harvest time. Only a few considered spaces and borders unnecessary.

*Frequency of Check Plots.*—In answer to the question, "What is your practice as regards the frequency of check plots?", 33 answers were received. It was found that many of the stations did not follow any one standard system of arranging check plots and that in many cases the practice varies according to the particular experiment. At the same station, series of plots laid out at different times may have checks located at different intervals. Thirteen of the stations answering the question thus have more than one system in operation. It was not always possible from the answer to tell how many different systems

are in use. In the following classification of the number of stations using different frequencies of checks, some overlapping occurs, as some are using more than one system. At 4 of the stations, systems of plotting are used in which every other plot is a check. The system of having every third plot a check is used at 21 of the stations. Six of the stations reporting are using every fourth plot as a check; 10, every fifth; 3, every sixth, and 4, every tenth. One of the stations is using a check near the beginning and near the end of each series of plots. In one case only one check is used, located at the beginning of each series, and at two of the stations the checks are located at irregular intervals according to convenience or soil variation. In many cases, perhaps the majority, the field-plot experiments reported were laid out years ago and a considerable number of them were laid out shortly after the establishment of experiment stations in this country, when the men in charge had little experience back of them. In making suggestions for laying out new series of permanent plots for soil-fertility investigations, the great majority of those replying favored the use of frequent and regularly distributed checks. In most cases it is considered desirable to have a check plot on one side or the other of each specially treated plot.

*Treatment of Check Plots.*—To the question, "How should check plots be treated?", 32 replies were received. Here again the practice varies, some giving the check plots a standard maintenance treatment, but in the majority of cases the check plots receive no treatment in the way of additions to the soil other than the crop rotation. A few of the stations are using treated check plots in some experiments and untreated check plots in others. In classifying the replies to this question, it was found that the answers were not always definite. At least 7 of the stations are giving the check plots some definite and regular treatment, while 18 are using totally untreated check plots only, altho 9 of them think it might be advisable to give the checks some regular treatment calculated to keep them in a normal state of productiveness. In discussing the question from the standpoint of future work, 24 stations out of 32 answering the questions favor giving the plots which are used merely for checking purposes a uniform standard manurial treatment calculated to keep them in a reasonably productive condition, provided that one or more untreated plots are included in each series to show what will happen to the land if crops are continually removed and nothing returned. The most commonly suggested treatment is a uniform dressing of manure. Some favor liming only, others a green manuring at certain regular intervals. Many of the workers along this line feel that the totally untreated plot becomes more and more unsatisfactory for checking purposes as the fertility runs lower and lower, and the results of the special treatments studied become unduly exaggerated. In a few cases, it is held that it is not possible to devise a system of treating check plots that will maintain uniformity, and it is believed that difficulties might arise which would be more serious than those connected with totally untreated checks.

*Methods of Computing Results Through Check Plots.*—To the question, "How should check plots be used in computing the results of field experiments?", 34 replies were received, but 6 of them were not definite enough to admit of classification. Twelve investigators of the twenty-eight definitely answering the question use the check plots by calculating the normal check yield

for each of the plots lying between the actual checks by assuming that the soil changes gradually from one check plot to the next. The difference between this calculated check yield and the actual yield is taken as the effect of the special treatment given to the plot. In 5 cases, the practice is to compare the specially treated plots with the average of the two nearest checks. In 3 cases, each specially treated plot is compared with the average of all the checks in the series. In 1 case where every third plot is a check, the treated plot is compared directly with its adjoining check. In 3 cases, sometimes the first system and sometimes the second system is used. In 1 case, sometimes the first system and sometimes the third is used, and in 2 cases, sometimes the second system is used and sometimes the third. In 1 case, either the third or fourth system is used and in another, any one of the four systems is used, according to conditions. In 1 case, the probable error is computed for each plot and stated after the actual yield for that plot. From the foregoing it is seen that here again there is no uniformity among the stations in the system employed, some using one and some another of four or five different systems. Check plots are used in one way or another by all of the stations answering the questions. However, it is doubtful if there is justification for so many different practices. Altho actual practices differ so widely, the preponderance of opinion is in favor of the use of frequent and regularly distributed checks, giving the check plot some regular soil treatment to keep it in a condition of reasonable productiveness and employing the check in making corrections by calculating the probable check yield for each plot according to the variation between the two nearest checks.

### METHODS OF CONDUCTING EXPERIMENTS WITH CROPS.

A questionnaire relating to the methods used in conducting experiments with crops was sent to 76 agronomists. The principal questions related to the methods generally used in varietal, rate-of-seeding, date-of-seeding, method-of-seeding, and stage- or time-of-harvesting tests with small grain, cultivated crops, and hay and pasture crops in both field and nursery. Thirty-six replies to a part or all of the questions were received. These replies are summarized for each of the larger groups of crops as follows:

*Size and Dimensions of Plots Used for Varietal, Rate-of-Seeding, and Date-of-Seeding Tests with Small Grain.*—Thirty investigators reported the size of plots used for varietal, rate-of-seeding, and date-of-seeding tests with small grains. Of these, 2 use (not exclusively) plots larger than one-tenth acre in size. Twenty use plots varying in size from one-twentieth to one-tenth acre, 12 use plots less than one-twentieth but larger than one-eightieth acre, and 2 use plots one-eightieth acre in size or smaller. One investigator who uses fortieth-acre plots states that unpublished work indicates that one-eightieth acre is a good size.

Twenty-seven reports relating to varietal, rate-of-seeding, and date-of-seeding tests with rowed crops (corn, sorghum, cotton, cowpeas, soybeans, and potatoes) were received. Of these, 3 use plots larger than one-tenth acre, 18 use plots from one-tenth to one-twentieth acre, 16 use plots less than one-twentieth but larger than one-eightieth acre, and 5 use plots less than one-eightieth acre in size.

Twenty-nine investigators reported on varietal and rate- and date-of-seeding

tests with hay and pasture crops (alfalfa, clover, and grasses). Of these, 7 use plots larger than one-tenth acre, 21 use plots from one-twentieth to one-tenth acre, 8 use plots less than one-twentieth and more than one-eightieth acre, and 4 use plots one-eightieth acre in size or smaller. Most of those who use plots larger than one-tenth acre do so for pasture experiments.

Twelve reported miscellaneous tests such as stage of cutting and time of harvesting in which different sizes than those reported for other tests were used. Of these, 3 use plots larger than one-tenth acre, 8 use plots one-twentieth to one-tenth acre, 3 use plots less than one-twentieth acre but larger than one-eightieth acre, and 2 use plots one eightieth acre in size or smaller.

Summarizing all crops and kinds of experimental tests, it appears that slightly more than half of the agronomists use plots varying in size from one-twentieth to one-tenth acre. Very few use plots larger than one-tenth or as small as one-eightieth acre. For small grains and rowed crops, plots less than one-twentieth but larger than one-eightieth acre are used almost as much as the one-twentieth to one-tenth acre sizes. Plots larger than one-tenth acre are used more extensively for hay and pasture crops than for small grains or rowed crops.

Thirty-one reported the number of rows per plot for tests with rowed crops. Of these 8 use plots consisting of one row, 12 use plots consisting of two or three rows, and 27 use plots consisting of four or more rows per plot.

All experimenters who gave dimensions reported the use of long, narrow plots, the ratio of width to length varying from about 1 to 4 to about 1 to 200. The average ratio for all reporting is about 1 to 28 for small grains, 1 to 15 for rowed crops, and about 1 to 10 for hay and pasture crops.

*Number of Times Plots are Replicated.*—Thirty-three replies relating to varietal tests with small grains were received. Six of these report the use of single plots. Twenty-one duplicate some or all of their tests, 17 replicate from two[1] to four times, and 5 replicate their tests more than four times in all cases or when time and ground permit. For rate- and date-of-seeding tests, 3 experimenters use single plots, 17 duplicate their tests, 14 replicate two to four times, and 3 replicate more than four times.

For varietal tests with rowed crops, 7 investigators report the use of single plots, 20 duplicate their tests, 16 replicate two to four times, and 2 more than four times. For rate- and date-of-seeding tests with rowed crops, 5 use single plots, 13 duplicate, 9 replicate two to four times, and 1 more than four times.

Of those reporting tests with pasture and hay crops, 8 use single plots, 15 duplicate their tests, 9 replicate from two to four times, and 1 replicates more than four times. A number who used single plots indicated that they did so only when land and facilities for handling the work made it impractical to do otherwise. In fact, only one investigator reported the use of single plots exclusively. In this case and in most of the others reporting the use of single plots, check plots were used.

In interpreting results of experiments in which replicate plantings are made, 16 compute the "probable error" and 13 do not.

*Margins of Plots.*—An inquiry was made as to whether the margins were harvested with the plots, removed before harvest, or whether the alleys and roadways were seeded solid to prevent the crop receiving water and plant food

[1] That is, three plots of each variety.

from the adjoining areas. Thirty-four replies were received. Thirteen reported that the outside rows or margins were harvested and included with the plots. Fifteen do not include the outside rows or margins with the plot; i.e., the outer edges are removed before harvest. Six follow the practice of seeding the entire alleys and removing the crop before harvesting the plots.

Some or all of those who make no provision for eliminating the marginal effect use very narrow alleys and one includes a part of the alley with the plots in computing yields in order to compensate for the food and water secured from beyond the edges of the plots. One investigator in tests with small grains seeds winter wheat in the alleys in the spring.

The Colorado station has determined for irrigated plots the lateral movement of water and surrounds the plots with borders which extend beyond the limit of safety.

Twenty-five replied as to provisions being made to prevent insect or fungus damage to adjoining plots because of the proximity of especially susceptible varieties, dates of cutting (as, for example, leaf spot on alfalfa, which may spread from a plot which is not cut to the new succulent growth of an adjoining plot and do more damage than if the entire field was cut at the same time) or special methods of seeding or cultivation. Fifteen reported that no such precautions were taken. The remainder endeavored to prevent such damage by grouping susceptible varieties, by eliminating susceptible varieties as soon as discovered, by early harvest of severely damaged plots, and by control measures.

Thirty-two agronomists reported regarding provisions made to prevent errors in experimental tests with rowed crops due to the competitive effect of adjoining plots, as, for example, shading by unusually tall varieties of corn, or early planted lots in time-of-seeding tests. Fifteen reported that no provisions of this kind are made. Five of the remainder group the varieties, and ten eliminate or reduce errors of this kind by planting extra or guard rows.

*Variation in Size of Kernels in Varietal Tests.*—The question was asked whether any provision is made to insure a uniform number of kernels per acre in varietal tests in which varieties with different sized grains are included. Twenty-three replies were received. Eleven increase the rate of seeding for large-kerneled varieties. Of the remainder, 10 reported that they do not consider the variation in size important or else they consider it impractical to eliminate this source of error for small grains.

*Size and Dimensions of Nursery Plots.*—Of 17 experimenters who reported on the size and dimensions of nursery plots for small grain, 13 use rows approximately 1 rod in length. Four reported the use of rows greater in length than 50 feet and one uses rows 100 feet in length or longer. One reports that blocks 16 feet long by 50 inches wide are used and another reports the use of plots 5 feet square. Those who use rows usually space them 1 foot apart, but this distance varies from 8 inches to as much as 18 inches.

As to the number of rows per plot, 9 reported that single rows were used, 8 used plots consisting of from two to four rows, and 3 used plots consisting of five rows for some or all tests.

For pasture and hay crops, 4 reported the use of single row plots, 6 the use of 2-row to 4-row plots, and 1 the use of 10-row plots. One uses small blocks or squares.

*Replication of Nursery Plantings.*—For small grains, 4 indicated that they do not replicate their plantings, 5 duplicate their tests, 10 replicate from two to four times, and 6 replicate five times or more. For rowed crops, 5 do not replicate, 6 duplicate their tests, an equal number replicate from two to four times, and 2 replicate five times or more.

Four use single plantings for hay and pasture crops, 5 duplicate, 4 use from three to five plantings, and 1 replicates five times or more.

Of 23 who use or have used single rows for nursery plots only 7 make provision for eliminating error due to the competition of adjoining rows. The impracticability of entirely eliminating such errors appears to have been one of the chief reasons for using plots consisting of more than single rows. Practically all who use single rows attempt to prevent erroneous conclusions by recording any unusual sources of error, as when some rows fail to germinate or are killed by cold or other causes.

*Cooperative Experiments with Farmers.*—Of 30 who sent reports relating to cooperation with farmers all but 6 indicated that cöoperative experiments of some kind were conducted. All but 1 investigator consider them necessary. A few experimenters were emphatic in their expression of the necessity of such tests, while others appeared to consider them of little value from an experimental viewpoint.

*Experiments in Technic.*—Seven agronomists reported experiments now under way relating to the technic of conducting field experiments with crops, and others have work planned for prosecution after the war.

## GENERAL DISCUSSION.

It is fair to say that the results of this questionnaire show a very lively realization of the importance of accurate field tests and an earnest endeavor to reduce such errors as far as possible with the money, time, and land available for experimental work. Many state that tests would be replicated a greater number of times and greater accuracy would be secured if it were possible to do so. It is especially encouraging to note that less than 20 percent of those who sent in reports depend on single plots, but replicate their tests from one to several times.

One need only compare the methods in general use by agronomists ten years ago with those used at the present time to appreciate the great improvement in technic that has taken place. That there is an appreciable variation in the soil from plot to plot was just beginning to be realized at that time. The use of check plots was by no means common and replication of plots was scarcely thought of. Variation of the soil is now one of the accepted tenets of agronomic science, and agronomists now replicate their tests almost as frequently as they formerly depended on single plots.

No doubt much or all of this improvement in methods is due to the agitation which resulted in the appointment by the American Society of Agronomy of the first committee on the Standardization of Field Crop Experiments and to the excellent experiments relating to the technic of field experiments conducted by members of the Society.

It would be surprising if the questionnaire had failed to show that there is need of more information of several kinds. There is much uncertainty as to the necessity of removing the border rows of field plots before harvest. There

are those who contend that, as all plots are affected alike, the increase in yield due to the marginal effect is comparative and may be ignored, especially if the alleys are narrow. On the other hand, the fact that nearly half of those sending in reports remove the grain from the alleys at considerable expense and inconvenience at a very busy time of the year shows there are some who do not share this view.

Much remains to be done before it can be safely asserted that any given size of plot is best for a given purpose, and experimenters are perhaps even more in the dark as to the number of replications necessary or desirable for each set of conditions. In nursery tests it is apparent that not all are convinced of the necessity of avoiding all chances of error due to the competition of adjoining rows.

## Conclusion.

The committee regrets that the survey could not be made more complete. Questionnaires were directed to interested investigators at all of the State experiment stations, but only about 70 percent replied. The replies, however, include reports from all of the stations carrying on any considerable amount of field-plot experimental work and are sufficiently representative to give a fair idea of the various methods in operation. It will be seen from the foregoing summaries that there are great variations in the practices followed and many differences of opinion among the investigators concerned as regards the most desirable methods to follow. Circumstances, no doubt, alter cases and probably it would not be wise to lay down any hard and fast rules from our present knowledge of the factors involved. The relative merits of different systems must receive further study and the committee strongly recommends that more of the members in position to do so undertake experimental studies with a view to determining the best and most practicable methods for the different lines of investigation requiring field-plot experiments. Doubtless a certain amount of standardization is possible and the members of this society should work together to that end.

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Respectfully submitted,

A. T. WIANCKO,
F. S. HARRIS,
S. C. SALMON,
*Committee.*

## REPORT OF THE COMMITTEE ON TERMINOLOGY.

Your Committee on Terminology begs to report that, owing to the conditions arising out of the war, the work of the Committee has been practically suspended during the past year, but it is purposed now to continue it with vigor. Thus far four contributions to the subject have been published, and when the whole subject has been covered it is proposed that these be combined and published as an official glossary.

Yours very truly,

C. V. PIPER,
*Chairman of the Committee.*

## REPORT OF THE EDITOR.

Because of the increased cost of publication and the reduced income of the Society due to loss of members to military service and for other reasons, it has been necessary to curtail the year's volume of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY. Including the December number, the volume consists of 360 pages, as compared with 432 pages printed in 1917 and 400 pages printed in 1916. Not including the December number, the forms for which are not yet made up, the 1918 volume has included 41 papers by 55 authors, representing 19 States and the District of Columbia. This is one more paper than was included in the considerably larger volume of last year, showing a desirable tendency toward shorter papers. To illustrate these papers, 9 plates and 46 text figures have been used.

The editing of the JOURNAL has been accomplished with considerable difficulty, as the editor has been either traveling or on emergency work outside Washington during all except two months during the year. It has often been difficult to reach him promptly with papers for publication or with proof, and consequently the promptness and regularity of issuance of the JOURNAL has not been up to the desired standard. As a large agricultural library has not usually been at hand, it has been impossible to check many of the citations of literature, and therefore these have not always been as accurate or as uniform as could be wished. The editor has refrained from resigning only because he has felt that others who might do the work are as heavily loaded with emergency duties and perhaps as badly handicapped as he.

Necessarily, the size of the annual volume is dependent on the Society's income. It is hardly likely that printing costs will further increase, so that if the present membership can be maintained the 1919 volume should be at least as large as the one just published. With the favorable conclusion of the war, however, the Society's membership should be largely increased, and this increase will naturally bring prosperity to the Society's publication. The maintenance or the progress of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY is dependent largely on the whole-hearted support of the Society's membership.

The editor regrets exceedingly that it is not possible for him to attend the eleventh annual meeting of the Society, the first that he has missed since his official connection with the organization. He trusts that it will be a very interesting and successful one, and that it will mark the beginning of a new era of progress for the American Society of Agronomy.

Respectfully submitted,

C. W. WARBURTON,
*Editor.*

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